UNIVERSITY OF ALBERTA

THE ARCTIC LAMPREY OF GREAT SLAVE LAKE, N.W.T.

by

© DAVID GLEN BUCHWALD

A THESIS

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled, "The Arctic Lamprey of Great Slave Lake, N.W.T.", submitted by David Glen Buchwald in partial fulfilment of the requirements for the degree of Master of Science.

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ABSTRACT

The Arctic Lamprey (*Lampetra japonica* Martens) was investigated in the Great Slave Lake area of the Northwest Territories during the summers of 1966 and 1967.

Its distribution in Great Slave is primarily west of the Simpson Islands, i.e. in that part of the lake found in the Mackenzie Lowlands. Of 26 rivers examined, ammocoetes were found only in the Slave, Hay and Mackenzie.

Spawning occurs in June or early July in the Hay River system and prior to July 8 in the Slave River system. Average egg counts, based on 18 specimens was 21,415 (9,790 - 29,780).

Ammocoetes were usually taken from small back eddies along the river's edge. We were not able to determine satisfactorily how much movement occurs within the river. A mark and recapture technique suggested a total Hay River population of 27,927. This is undoubtedly low.

Length-frequency distributions suggest a stream life for ammocoetes of four years. The largest ammocoetes are found near the river's mouth. The composition of the ammocoete in the upstream beds changes as the summer progresses.

A growth study using marked ammocoetes was not successful.

Trunk myomere counts are similar to those obtained from Arctic Lamprey in the Mackenzie River system.

Descriptions for a group of tooth characters are given. These include measurements and cusp counts. Regression lines for 12 body measurements suggest changes in body proportions as the lamprey's life cycle progresses. Descriptions of ammocoete pigmentation suggest no differences between Hay River and Slave River forms. A distinct size difference does occur however,

as the Slave River ammocoetes average approximately 40 millimetres less in length than the Hay River ammocoetes.

Lamprey attachments were primarily on whitefish, cisco, inconnu and lake trout. The lake scarring rate is less than two per cent, and hence is not of economic importance.

Only 0.5 per cent of the fish examined had preyed upon lampreys.

Trianeophorus was found in the coelom of adult lampreys.

Lampetra is preferred as the generic name, rather than *Entosphenus* or *Lethenteron*.

The presence of a non-parasitic subspecies is postulated.

It is suggested that a dispersion of parasitic lampreys occurs from the Hay and Slave River mouths in late spring. This results in a large parasitic population in the northern part of the lake in the fall. Sexual maturation and cessation of feeding occurs in the winter. The adults migrate back to the rivers on the south shore to spawn in the spring.

ACKNOWLEDGEMENTS

I would like to express my appreciation to the Fisheries Research Board of Canada, for their support in this study and for the great deal of assistance provided. I would also like to thank them for the summers of 1964 and 1965, at which time I was employed as a summer assistant on Great Slave Lake.

I particularly wish to express my thanks to Dr. J. R. Nursall, Head of the Department of Zoology, University of Alberta, for his guidance and supervision and for critically reviewing the manuscript. Dr. D. D. Beatty also reviewed the manuscript.

Mr. J. J. Keleher was generous with his time and provided many helpful suggestions in the course of the study. Both he and his staff were of great assistance in the processing of the IBM data.

Conrad Haight of Hay River was generous in his assistance. His tolerance in teaching an amateur the intricacies of fishery techniques is deserving of my deepest thanks. Aside from this, his personal friendship during my four summers with the Fisheries Research Board will never be forgotten.

I am indebted to the people of the Hay River area, without whose assistance this study would have been impossible. They include the staff of the Department of Fisheries, especially Ken Roberts.

The commercial fishery was frequently utilized in the collection of information. To the companies concerned and to the fishermen themselves, I express my appreciation.

Bill Bond, Brian Smiley, and Gregory Bromely were generous with their assistance in the field.

The lonely sunsets flare forlorn
  Down valleys dreadly desolate;
The lonely mountains soar in scorn
  As still as death, as stern as fate.

The lonely sunsets flame and die;
  The giant valleys gulp the night;
The monster mountains scrape the sky,
  Where eager stars are diamond-bright.

So gaunt against the gibbous moon,
  Piercing the silence velvet-piled,
A lone wolf howls his ancient rune—
  The fell arch-spirit of the Wild.

O outcast land! O leper land!
  Let the lone wolf-cry all express
The hate insensate of thy hand,
  Thy heart's abysmal loneliness.

....*The Land God Forgot*
by Robert Service

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I. INTRODUCTION

The Fisheries Research Board of Canada has been interested in the Great Slave Lake commercial fishery for a number of years. As a predator of commercially important fish in Great Slave Lake, the Arctic Lamprey is of some interest. It was decided to begin a study in the summer of 1966.

A. Synonomy

1. The Trivial Epithet:

The Arctic Lamprey, *Lampetra japonica* (Martens) 1868, has been known to be present in Great Slave Lake since 1823 (Richardson 1823). Synonyms include:

Petromyzon fluviatilis: Richardson, 1823:705-728

Petromyzon borealis: Girard, 1858:377; type locality—Great Slave Lake

Petromyzon japonicus: Martens, 1868

Ammocoetes aureus: Bean, 1881:159; Turner, 1886:87-113

Lampetra aurea: Preble, 1908:503-515, Halkett, 1929

Entosphenus japonicus: Creaser and Hubbs, 1922:5 (subgenus *Lethenteron:* Creaser and Hubbs, 1922:5); Dymond, 1947:1-36; Hildebrand, 1948

Lampetra borealis: Jordan, 1930 (reprinted 1962):10

Entosphenus lamotteni: Wilimovsky, 1954:274-294

Lampetra japonica: Walters, 1955

Lethenteron [*japonica*]: Vladykov and Follett, 1967

Presently the trivial epithet for this species is *japonica* Martens, 1868. However this is antedated by *borealis* Girard, 1858, and this is the earliest available trivial epithet for this species. Hence while *borealis* is correct, *japonica* is in more general usage.

B. Generic placement

A state of confusion surrounds the generic status of the Arctic Lamprey.

The question is whether to consider it to be *Lampetra, Entosphenus* or *Lethenteron*. The recent Royal Ontario Museum checklist gives *Lampetra* as the accepted genus.

Lamprey taxonomy to date has been largely based upon tooth characters. The major contributors to descriptions of holarctic lampreys have been Creaser and Hubbs (1922), Berg (1931) and Vladykov and Follett (1967). Recently Lindsey and McPhail (1968) have entered the controversy.

The genus *Entosphenus* can be removed from the argument, in that Berg, Creaser and Hubbs, and Vladykov and Follett all agree that it has a tricuspid supraoral lamina and four endolaterals. This is not true of the Great Slave species. Lindsey also mentions that *Entosphenus* has 50 to 63 fine plates on the longitudinal tooth plate whereas *Lampetra* has 0 to 26.

The presence or absence of posterials has been a major generic character in the past. Vladykov and Follett (1967) consider their absence to be a characteristic of the genus *Lampetra*. Berg (1931) feels they may be present or absent in this genus while Creaser and Hubbs (1922) also consider them to be absent in *Lampetra*. Creaser and Hubbs (1922) have also suggested the existence of the subgenus *Lethenteron* of the genus *Entosphenus*. Their description of the genus *Entosphenus* excludes the Great Slave Lake lamprey, but this subgenus is considered by them to be the Arctic or Siberian lamprey. Vladykov and Follett (1967) have decided to elevate this subgenus to full generic stature. Vladykov and Follett (1967) have separated *Lampetra* from *Lethenteron* on two major characters: 1) posterials are absent in *Lampetra* and present in *Lethenteron*, 2) in *Lethenteron*, but not in *Lampetra*, one or more small cusps may occur in the middle of the bridge of the supraoral lamina.

Berg (1931) has stated that posterials may be present or absent in *Lampetra*. Lindsey and McPhail (1968) point out that posterials may be present, absent, or incomplete in a single species. This certainly puts in

question their taxonomic validity at the generic level.

Adult lampreys examined from Great Slave Lake always had a complete row of posterials. Of the 109 examined only one had a small median cusp on the bridge of the supraoral lamina. With the value of the posterials as a generic character so much in question, the genus must be *Lampetra*. After eliminating the other characters, according to Vladykov and Follett (1967) it would be *Lethenteron* on the basis of a median cusp on the supraoral lamina in 0.9 per cent of my specimens. This is a poor basis and hence I shall consider it to be *Lampetra* until further evidence to the contrary becomes available.

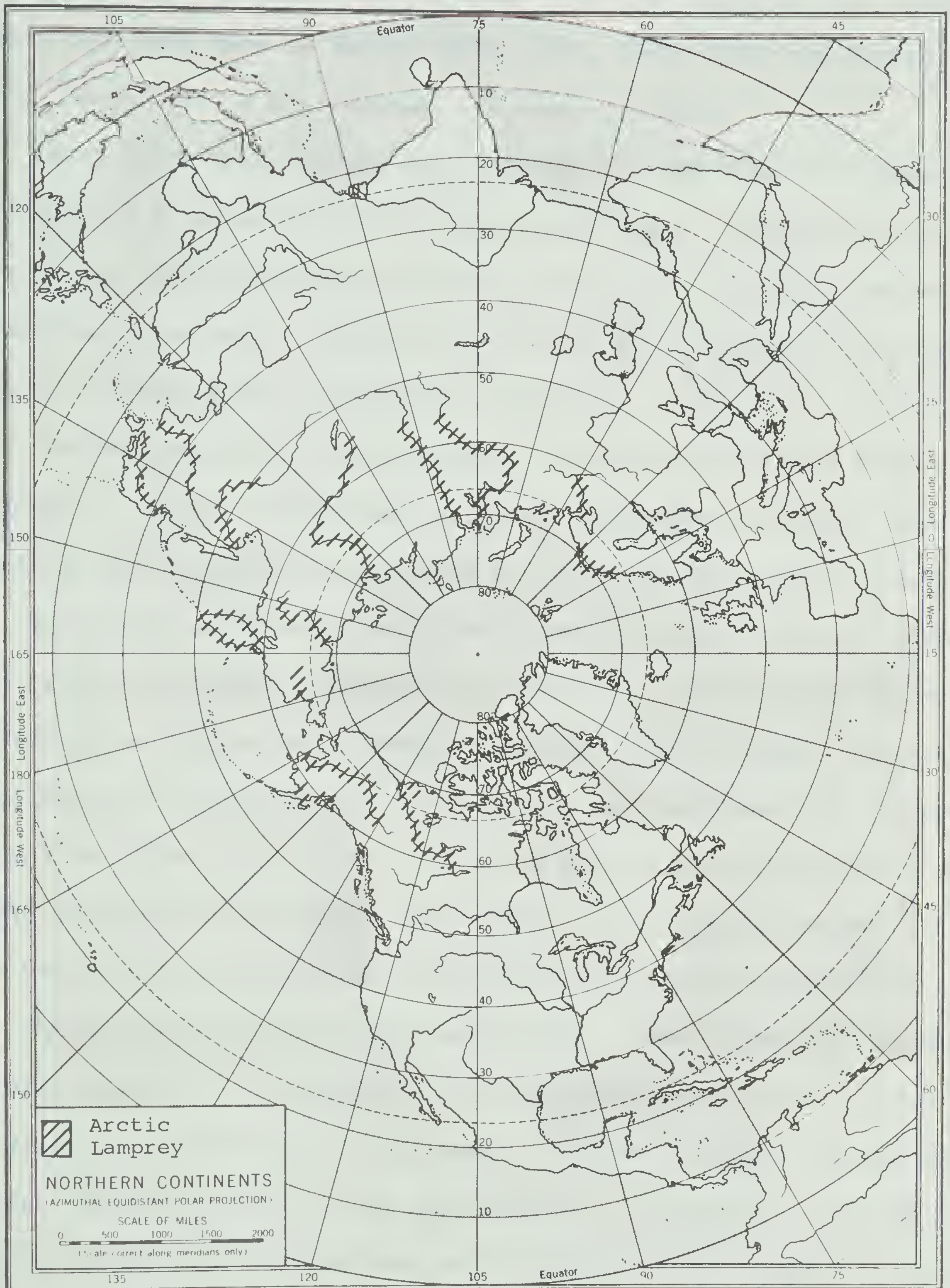
The species name has not been in question.

II. DISTRIBUTION

The Arctic lamprey is reported from the basin of the Japan Sea, Amur River, Kamchatka, Suchan River and Korea. As *Lampetra japonicus septentrionalis* (Berg) it is found in the Western part of the Arctic from the White Sea to the Ob basin, and as *Lampetra japonicus kessleri* (Berg) in the rivers of Siberia (Berg 1931). Ushakov (1950) records *Lampetra japonica* as being in Arctic rivers and Tambs-Lyche (1963) records *Entosphenus japonicus* in Norway.

In North America it is recorded from the Yukon River, Mackenzie River, Anderson River, Bristol Bay, Tara River, Iliamna River, Naknek River, Kenai Peninsula, Great Slave Lake and Artillery Lake (Heard 1966, Lindsey and McPhail 1968, Walters 1953, 1955, Wilimovsky 1954). Figure 1 shows the distribution of Arctic Lamprey.

Figure 1. *World distribution of Arctic Lamprey*



NYSTROM SERIES OF DESK MAPS No. D 196 A. J. NYSTROM & CO., CHICAGO

III. STUDY AREA

Descriptions of Great Slave Lake in both its physical and biological aspects have been made by Rawson (1950, 1951, 1953, 1956) and Kennedy (1953, 1954). Only a few comments are necessary here.

Great Slave Lake lies between latitude 61° and 63°N and longitude 109° and 117° W in the District of Mackenzie, N.W.T. The east arm and north shore are in Precambrian rock while the west and much of the south are in the Mackenzie Lowlands. Its total area is 10,430 square miles and maximum depth in the east arm is 614 metres (2,075 feet). Effectively west of 113°W the mean depth is 41 metres whereas in Christie Bay mean depth is 249 metres. Figure 2 shows some of the more important locations on the lake, as well as the statistical areas used by the Fisheries Research Board.

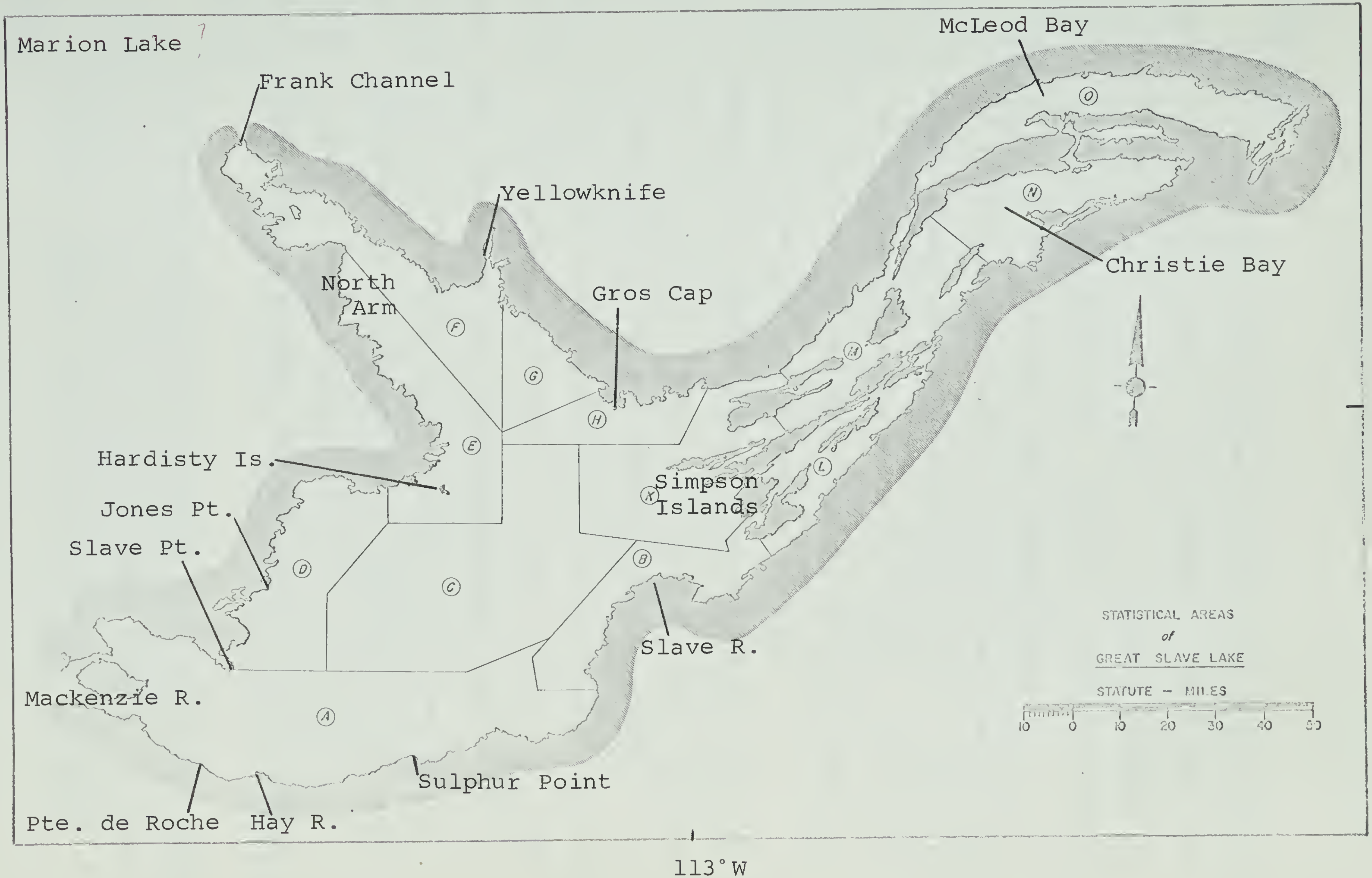
The rivers of the west and south shore of the main lake are generally quite turbid. They drain muskeg or taiga regions. In contrast, those of the Precambrian region are extremely clear and have rock beds. An average annual inflow of approximately 118,000 cubic feet per second is represented by the Slave River. The effect of this is found all along the south shore. A distinct break can be seen in the Simpson Islands region between the clear water of the east arm and the turbid water of the Slave River.

The Hay River drains 19,200 square miles. Near Enterprise on the Mackenzie highway it is blocked by Alexandra and Louise Falls. Within approximately one half mile of the mouth it passes through a series of islands. Generally the river is very shallow. In contrast, the Slave River is navigable as far upstream as the Rapids of the Drowned at Fort Smith.

There are 26 species of fish in the lake (Keleher 1964). Those of most importance in this study as lamprey prey or predators are: lake trout

(*Salvelinus namaycush* Walbaum), lake whitefish (*Coregonus clupeaformis* Mitchill), northern pike (*Esox lucius* Linnaeus), yellow walleye (*Stizostedion vitreum* Mitchill), cisco (*Leucichthys* spp.), inconnu (*Stenodus leucichthys* Guldenstadt), longnose sucker (*Cystomus cystomus* Foister), and burbot (*Lota lota* Linnaeus) (Kennedy 1953, 1954; Rawson 1951; Scott 1967).

Figure 2. *Great Slave Lake showing areas referred to in this study. The letters represent statistical areas used by FRBC.*


Marion Lake
Frank Channel
Yellowknife
North Arm
Gros Cap
McLeod Bay
Christie Bay
Hardisty Is.
Jones Pt.
Slave Pt.
Simpson Islands
Slave R.
Mackenzie R.
Sulphur Point
Pte. de Roche
Hay R.
A
B
C
D
E
F
G
H
K
L
M
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62°N
113°W
STATISTICAL AREAS
of
GREAT SLAVE LAKE
STATUTE - MILES
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20
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40
50

IV. MATERIALS AND METHODS

A. Biological

In the course of the study, data were collected from 3,076 ammocoetes, 78 immature and 112 adult lampreys. This represents 523 ammocoetes, two immature and 31 adults from the Slave River. All remaining specimens are from Great Slave Lake and the Hay River, except for 13 ammocoetes from the Mackenzie River. No ammocoetes were taken from Great Slave Lake.

All adults from Great Slave Lake were obtained from commercial fishermen, either by Fisheries Research Board summer assistants prior to 1966, or as a result of a two dollar reward program during 1966 and 1967. Adults from Fort Smith on the Slave River had become trapped in an inlet reservoir at the water treatment plant and were collected at one time.

All ammocoetes and immature lampreys taken from the Hay, Slave and Mackenzie Rivers were taken with electro-shocking gear. This involved the use of a portable 1750 watt, 110 volt alternating current generator. An extension cord was run to two electrode paddles, one of which had an on-off microswitch. Shocking was always done by two people, primarily for safety reasons. Each operator carried a collecting net and an electrode while working across an area. Ammocoetes were captured when they attempted to escape. Effectiveness varied with turbidity, lighting and likely, water conductivity (McCauley 1960). Polaroid glasses were very useful in reducing sunlight glare on the water, making it easier to see the struggling ammocoetes.

Gill netting was the major means of capture of the 15,502 fish examined for lamprey scars and the 1,283 fish used for stomach analysis. Also used was electro-shocking, angling, fyke-netting, spearfishing, seining and trawling.

Specimens to be kept were killed with seven per cent formalin and after fixation were transferred to 50 per cent isopropyl alcohol.

In 1967 a mark and recapture program was carried out on the Hay River. Subcutaneous injections of cadmium sulfide, mercuric sulfide or lampblack were used as markers. A total of 537 ammocoetes were marked in attempts to determine population size, migration and growth. The procedure is that outlined by Hansen and Stauffer (1964).

During the summer of 1966 I was mainly concerned with determining what rivers entering Great Slave Lake had lamprey populations. Twenty-six rivers were examined (Figure 3) with electro shocking gear. The Fisheries Research Board motor vessel *Stenodus* was used for transportation. An attempt was also made to find a spawning river in the north arm area, which involved a trip by road to Yellowknife.

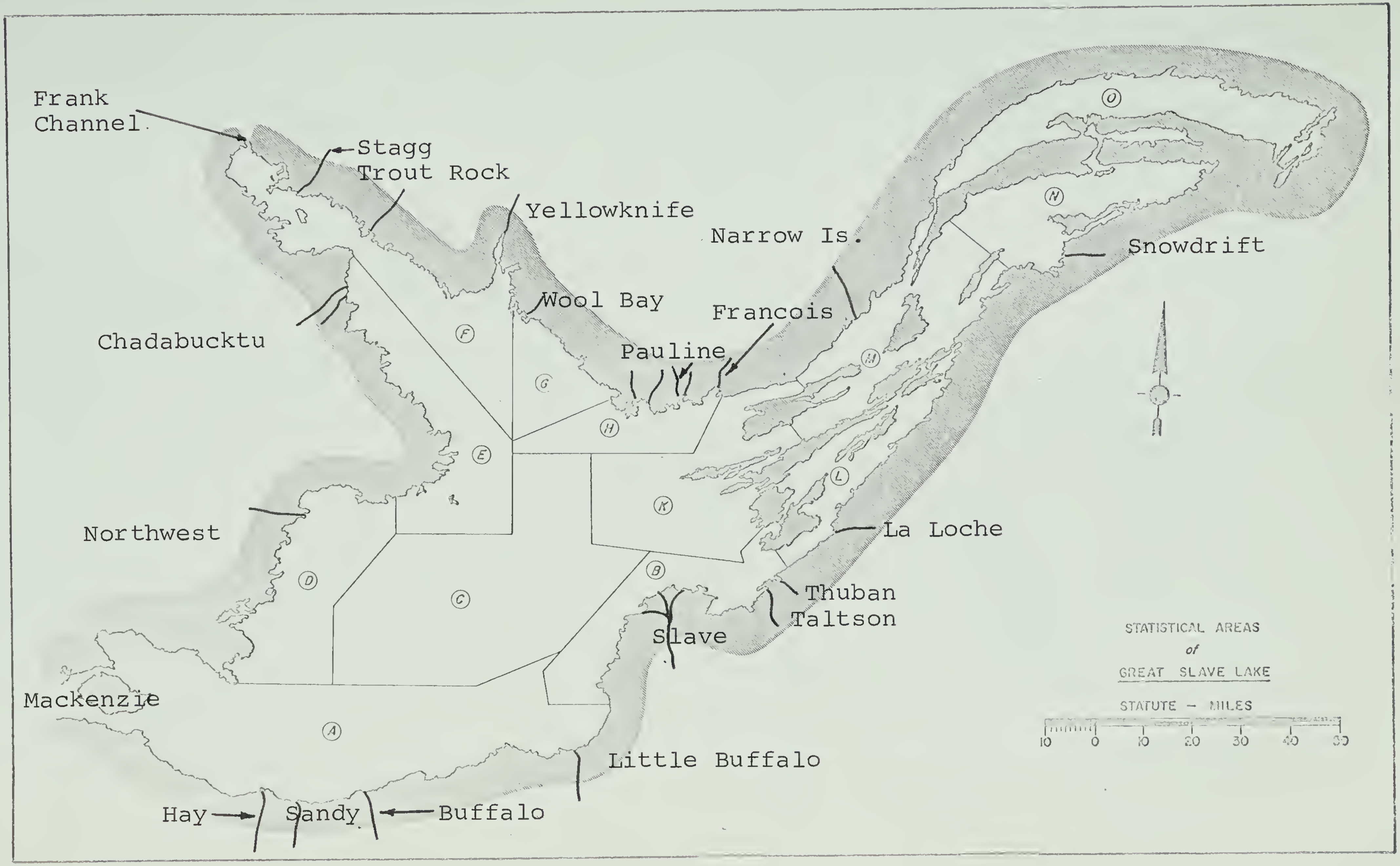
During the summer of 1967 I made a more detailed study of the Hay River situation and additional specimens were collected from the Slave River. A further attempt was made to locate lampreys in the Fort Rae-Yellowknife region.

Ammocoete beds in the Hay River were numbered 1 to 7 in a series from the mouth to mile 15 on the Mackenzie Highway (Figure 4).

Five-inch mesh gill nets were kept in the Hay River from June 1, 1967 to August 9, 1967 in order to obtain fish. A series of four trap nets was used from June 3, 1967 to August 9, 1967 in order to capture spawning adult lampreys or migrating ammocoetes. Only two adults and ten ammocoetes were captured.

As it became apparent that the trap nets were proving unsuccessful another technique was tried. On the assumption that adults may migrate upstream at night, on June 26, 1967 part of the West Channel of the Hay River was barricaded off, using a series of four electrodes. A hand

Figure 3. *Rivers entering Great Slave Lake which were examined for lamprey populations.*


Frank Channel
Stagg
Trout Rock
Yellowknife
Narrow Is.
Snowdrift
Wool Bay
Francois
Pauline
Chadabucktu
Northwest
La Loche
Thuban
Taltson
Slave
Mackenzie
Little Buffalo
Hay
Sandy
Buffalo
A
B
C
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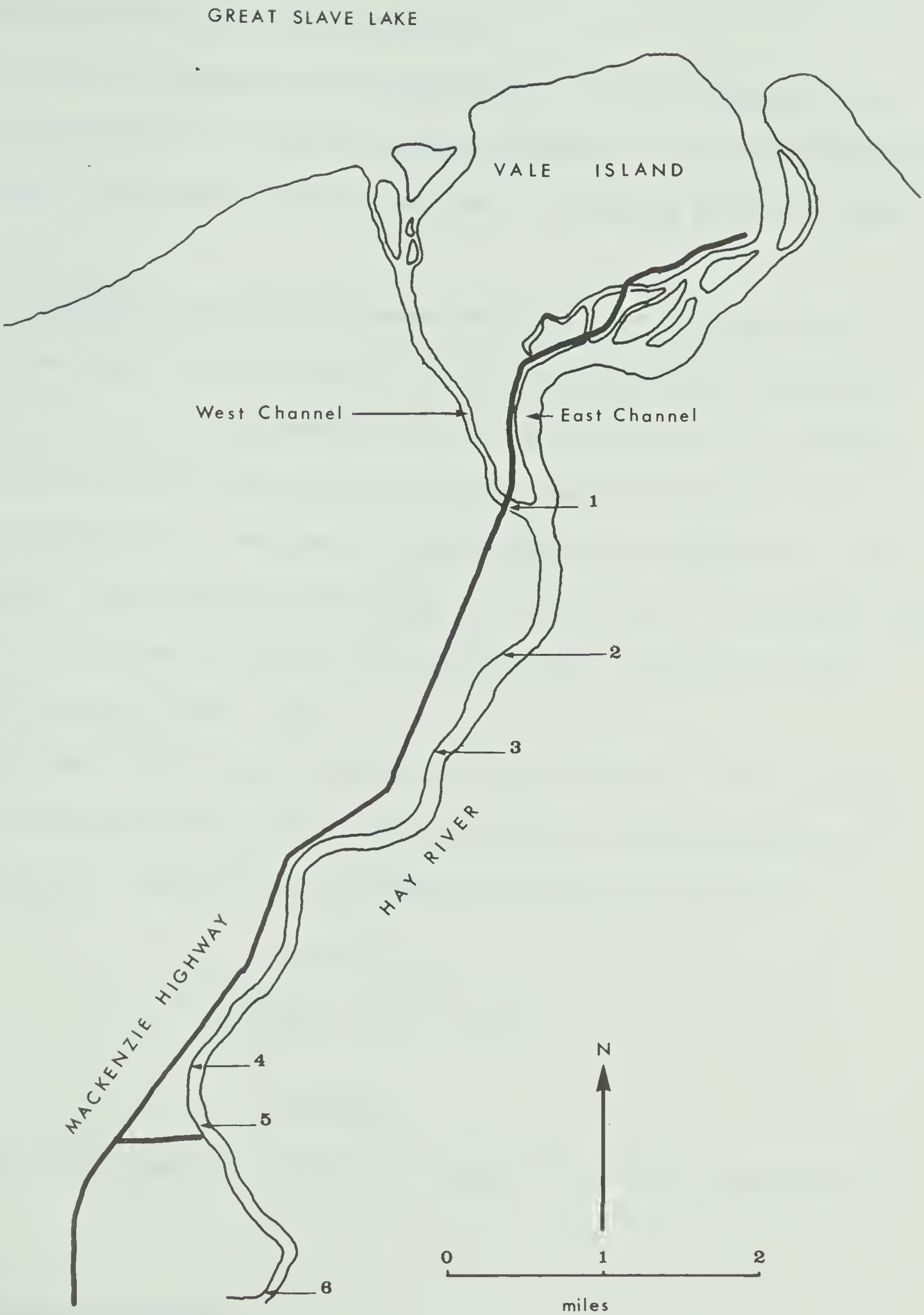
STATISTICAL AREAS
of
GREAT SLAVE LAKE
STATUTE - MILES
10 0 10 20 30 40 50

Figure 4. *Ammocoete beds on the Hay River. Bed 7 is located approximately eight miles upstream from bed 6.*


GREAT SLAVE LAKE
VALE ISLAND
West Channel
East Channel
1
2
3
HAY RIVER
MACKENZIE HIGHWAY
4
5
6
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0
1
2
miles

operated microswitch controlled the setup from about 20 yards downstream. A powerful light was also run off the generator. From 2030 until 0130 was spent there but only fish were seen.

In 1967, 40 ammocoetes were transferred to three aquaria at the Hay River office of the Fisheries Research Board to see if they could be kept alive. No problems were encountered. A sand-mud preference test was done.

All lampreys captured were measured for length. In addition, 81 adults from Great Slave Lake and 31 from Slave River were examined for a series of meristic, morphometric and sexual characters. One hundred and seventy-five ammocoetes from Slave River and 354 from Hay River were examined for meristic, morphometric and pigmentation characters. Also 46 immatures were examined for morphometric characters. The methods used were those described by Hubbs and Trautman (1937), Hubbs and Lagler (1958) and Vladykov (1949, 1960).

Egg counts were done on 18 adults using Vladykov's (1951) method.

Fish examined for lamprey attacks had both location and state of wound recorded. Lamprey attack positions are shown in Figure 5.

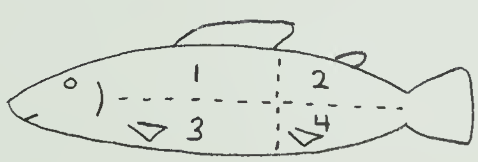


Figure 5.

When time permitted, length and weight of the fish examined were taken.

B. Physical and chemical

Mud samples were taken from known ammocoete beds. These were run through a set of U.S. Standard Sieves in order to determine particle

composition.

Water from most rivers visited in 1966 was chemically analyzed. Water analysis was done fortnightly on the Hay River during 1967 summer. A direct reading-engineer's laboratory Hach kit was used.

During 1967 daily temperature and depth information was taken from the Hay River.

C. Time periods

IBM analysis for some of the data obtained required the use of time periods. Reference will frequently be made to these two week periods. Relevant periods are as follows:

May 1 to 15	09	July 16 to 31	14
May 16 to 31	10	August 1 to 15	15
June 1 to 15	11	August 16 to 31	16
June 16 to 30	12	September 1 to 15	17
July 1 to 15	13	September 16 to 30	18

V. BIOLOGY

A. Life cycle

Recent studies, especially on some of the five Great Lakes species, have shown that most lampreys have similar life cycles. All known species spawn in fresh water. Spawning is usually in shallow water over a gravel bottom, with the adults dying shortly after. The ammocoete larva hatch in a few weeks and drift downstream to settle in eddies and backwaters. Here they burrow into the mud and filter feed on plankton and detritus in the river system. After a number of years, they undergo a metamorphosis and emerge as adult lampreys. They then leave the ammocoete beds and move downstream into oceans or remain in the stream.

At this point the life cycle of parasitic and non-parasitic species diverges. The parasitic lampreys feed as adults. Eventually they mature sexually and undergo a series of morphometric changes before returning to the rivers to spawn.

The non-parasitic species do not feed as adults but simply mature and spawn. These usually have noticeable sexual development at the time of metamorphosis (Hubbs 1925; Hubbs and Trautman 1937). In the European brook lamprey (*Lampetra zanandreai* Vladvkov) metamorphosis and sexual maturity are coincident (Zanandra 1961).

B. Distribution in Great Slave Lake

A survey during the summer of 1966 revealed lampreys to be present only in the Mackenzie, Slave and Hay Rivers. Of the rivers entering on the south shore, both the Buffalo and Little Buffalo Rivers appeared suitable for ammocoetes. While it has not been demonstrated it may well be that the sulfate concentrations (43 to > 300 ppm) are inhibitory.

The rivers of the Precambrian region are extremely clear with rock

bottoms. Hence there is little suitable ammocoete habitat. Often they are blocked by falls a short distance from the mouth. The majority of the remaining rivers are very shallow and likely freeze to the bottom in the winter.

It is interesting to consider the Mackenzie River. If this represents a spawning river, then ammocoetes when hatched would be lost downstream to the Arctic Ocean. The presence of ammocoetes is the only evidence of spawning in the Mackenzie.

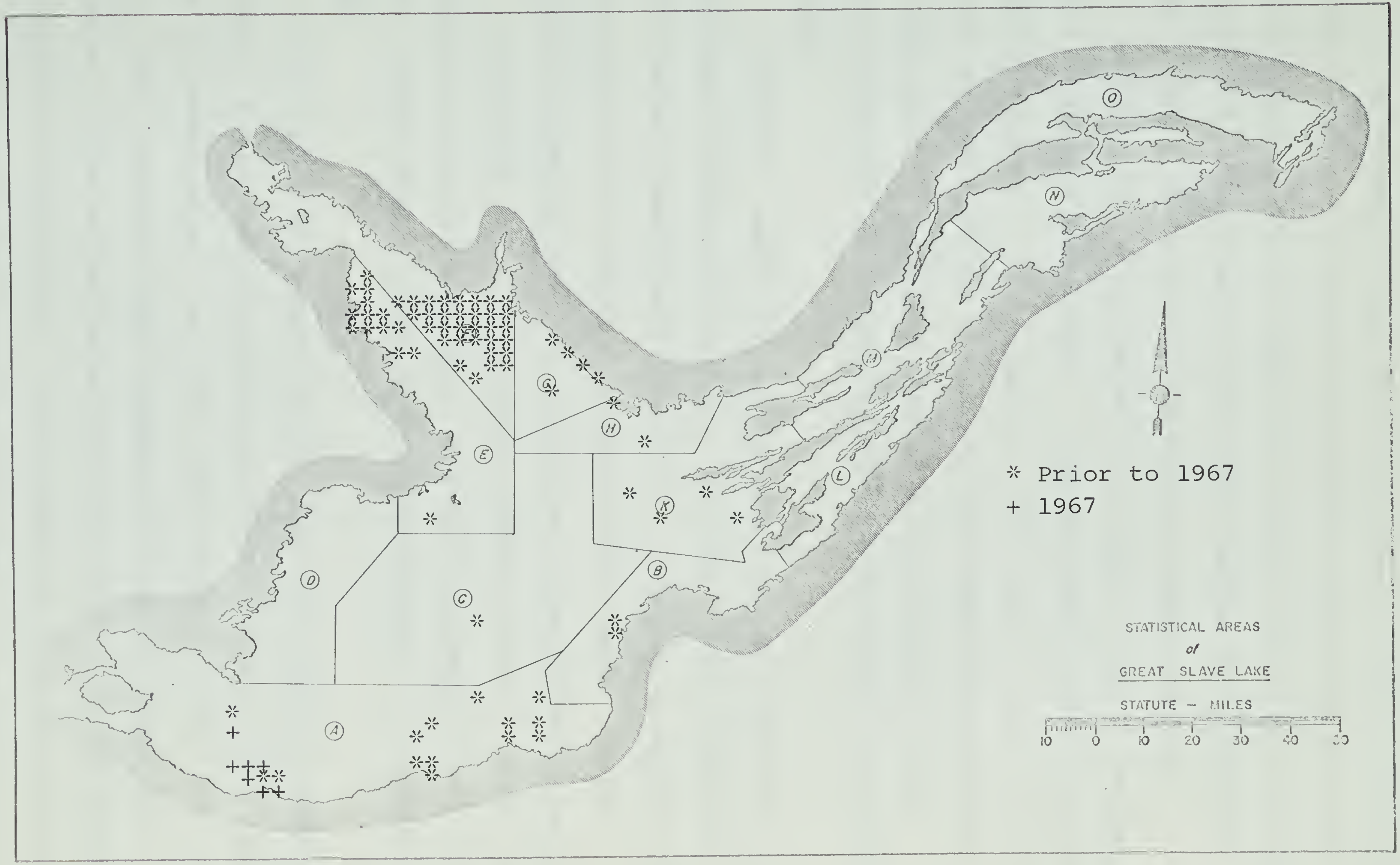
Adults examined from Great Slave Lake represent collections made over several years. These collections may have been affected by closure to commercial fishing of the lake, when quotas are met. These areas are not the same as Fisheries Research Board statistical areas as shown in Figure 2. Mainly affected is the area west of a line connecting Jones Point and Sulphur Point. The remainder of the lake is usually fished throughout the summer.

Areas are closed to commercial fishing in the vicinity of settlements in order to allow a domestic fishery for food and dogfood. McLeod Bay is also closed as many sport fishing lodges are located there.

As can be seen (Figure 6) lampreys have only been taken in the western half of the lake. Never has a lamprey been recorded east of the Simpson Islands nor does scarring information suggest their presence. This is not consistent with Walter's (1955) report of lamprey spawning in the Artillery Lake region.

The complete lack of specimens from FRB area D is likely because it is seldom fished after early July. Also I have no evidence of spawning streams in that area; indeed very few creeks occur along that shore. Frequently rivers and streams shown on the available maps for this region are non-existent, incorrectly positioned or misrepresented.

Figure 6. *Distribution of adult lampreys taken from Great Slave Lake, N.W.T.*



O
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D
C
B
A
* Prior to 1967
+ 1967
STATISTICAL AREAS
of
GREAT SLAVE LAKE
STATUTE - MILES
10 0 10 20 30 40 50

It can be seen that there is a concentration of adults in the north arm region representing specimens taken mainly during the fall of 1964. This concentration does not appear to be isolated to this year, as fishermen frequently mention that they have caught lampreys here late in the summer fishery. Several per net seems to be a common occurrence.

Associated with this situation is an attempt to explain the population source and possible spawning area. A trip was made by road to the Yellowknife region from August 9, 1966 to August 14, 1966 in order to check the area. Reports had reached the Hay River office about lamprey being present in the Stagg River. A thorough shocking of the river produced nothing. Further shocking on the Yellowknife River and Frank Channel gave negative results.

Occasionally lamprey have been recorded from pike stomachs from the area between Yellowknife and Gros Cap. With this in mind on August 20, 1966 I checked a creek flowing into Wool Bay. Shocking was negative and 41 pike examined had no evidence of lamprey in their stomachs. Further examination along this shore was not done due to time and navigation problems.

In 1967 from July 19 to 23 another attempt was made to locate a river population in the north arm region. On this trip the Marion River, Yellowknife River, Mosquito Creek and Trout Rock Creek were examined. No ammocoetes were found.

While at Fort Rae lamprey specimens were shown around the community in hope of gaining further information on distribution and perhaps stumbling upon the spawning area. I met Father Amorous who has worked in that area for 16 years, speaks the Dogrib language and is himself an avid gill net fisherman. He was not familiar with any river in the area which fitted my description as being suitable. All the rivers were clear with rocky bottoms.

Both through Father Amorous and Chief Bruno of the Dogrib Indians I

was able to talk to a large number of natives. Two reported taking adults from Marion Lake in past years. One had been taken in the spring of 1967. Others reported seeing lampreys in nets off Mosquito Creek while many were reported from the Whitebeach region. This represents the north arm boundary to commercial fishing and the furthest north records of captured lampreys. None had seen an ammocoete.

The mystery of the source of the north arm lampreys remains unsolved.

Reports of additional specimens must be regarded with caution, as few inhabitants can recognize a lamprey. Many confuse them with leeches.

Scarring information shows negligible values east of the Simpson Islands (Table 8). This will be considered further under parasitism.

Shocking at Fort Fitzgerald, above the Rapids of the Drowned on the Slave River, gave negative results. Hence I was not able to obtain an Alberta record of Arctic Lamprey.

C. Spawning

1. Area and time. The sex ratio of the adults is close to one and one (Table 1).

Changes which can be noticed in maturing lampreys are:

1) the teeth become blunt and non-functional
2) the intestine becomes degenerate
3) the coelom becomes full of gonads
4) the length becomes shorter (Zanandrea 1961)
5) in the female a large anal fin develops
6) in the male a prominent genital papilla often appears.

At no time in the study were spawning lamprey or spawning grounds located.

Trap nets in the Hay River during the summer of 1967 captured but two adult lamprey. These were taken on June 14 and June 27. The June 14th specimen appeared to be in post spawning condition with a few large eggs in the coelom, blunt teeth and a well developed anal fin (Figure 7). It was 16.8 centimetres long.

The June 27th specimen was a male with gonads in prespawning condition. The teeth were blunt and it was 22.6 centimetres long. This specimen was the characteristic grey of the lake lampreys while the June 14th one was very brown (Figure 8).

It appears that spawning occurs in late or middle June. The small size of the adults (Figure 9) at this time cannot be explained by immatures as transformation does not occur until August. That intestine width at this time is very small, most likely degenerate, is indicated by Figure 10. Similarly Figure 11 shows that Great Slave Lake adults after the first week in July are seldom mature. All Slave River adults were in spawning condition but it must be realized that these were all collected on July 8, 1967. At what time they were trapped is unknown.

Three ammocoetes taken at bed 6 on the Hay River on July 11, 1967, were but 1.2 centimetres long. Sea lamprey *(Petromyzon marinus)* information from the Great Lakes region suggests that within two weeks eggs hatch to prolarvae and within three weeks yolk absorption occurs and they become larvae (Applegate 1951; McCauley 1963). At one month they are 1.0 cm (Lennon 1955). Young (1962) mentions that with *Lampetra fluviatilis* a newly hatched larvae is approximately seven millimetres in length. While this information is from other species it would suggest that the Hay River ammocoetes may be from three to six weeks old. Spawning would then be some time in June.

Heard (1966) reports spawning time in the Naknek system from May 28th to July 2nd. This is within a few degrees of Great Slave Lake's latitude. He

Table I. *Sex ratio of 109 adult lampreys.*

Table II. *Egg counts from 18 mature female lampreys.*

Location	Male	Female	Number
Hay River	1	1	6
Slave River	1	0.63	31
Great Slave Lake	1	1.19	72
Total	1	0.98	109

Lamprey No.		Location	Anterior part of ovary	Posterior part of ovary	Total
A	1014	G.S.L.	22,629	22,629	22,732
A	1171	G.S.L.	19,210	19,127	19,168
A	1178	G.S.L.	14,543	15,103	14,823
A	1204	G.S.L.	19,602	19,146	19,374
B	1342	G.S.L.			9,790
B	1357	S.R.			17,043
B	1360	S.R.			19,876
B	1362	S.R.			22,230
B	1365	S.R.			27,302
B	1366	S.R.			26,670
B	1373	S.R.			22,797
B	1374	S.R.			24,365
B	1375	S.R.			26,430
B	1377	S.R.			29,780
B	1380	S.R.			14,747
B	1381	S.R.			27,920
B	1384	S.R.			20,999
	1340	H.R.			19,428

Great Slave Lake mean 17,177 Range 22,732 to 9,790

Slave River mean 23,347 Range 14,747 to 29,780

Figure 7. *June 14th specimen from Hay River. Note the well developed anal fin.*

Figure 8. *June 27th specimen from the Hay River. Note the colour.*


1343

Figure 9. *Seasonal distribution of size of adult lampreys from Great Slave Lake.*

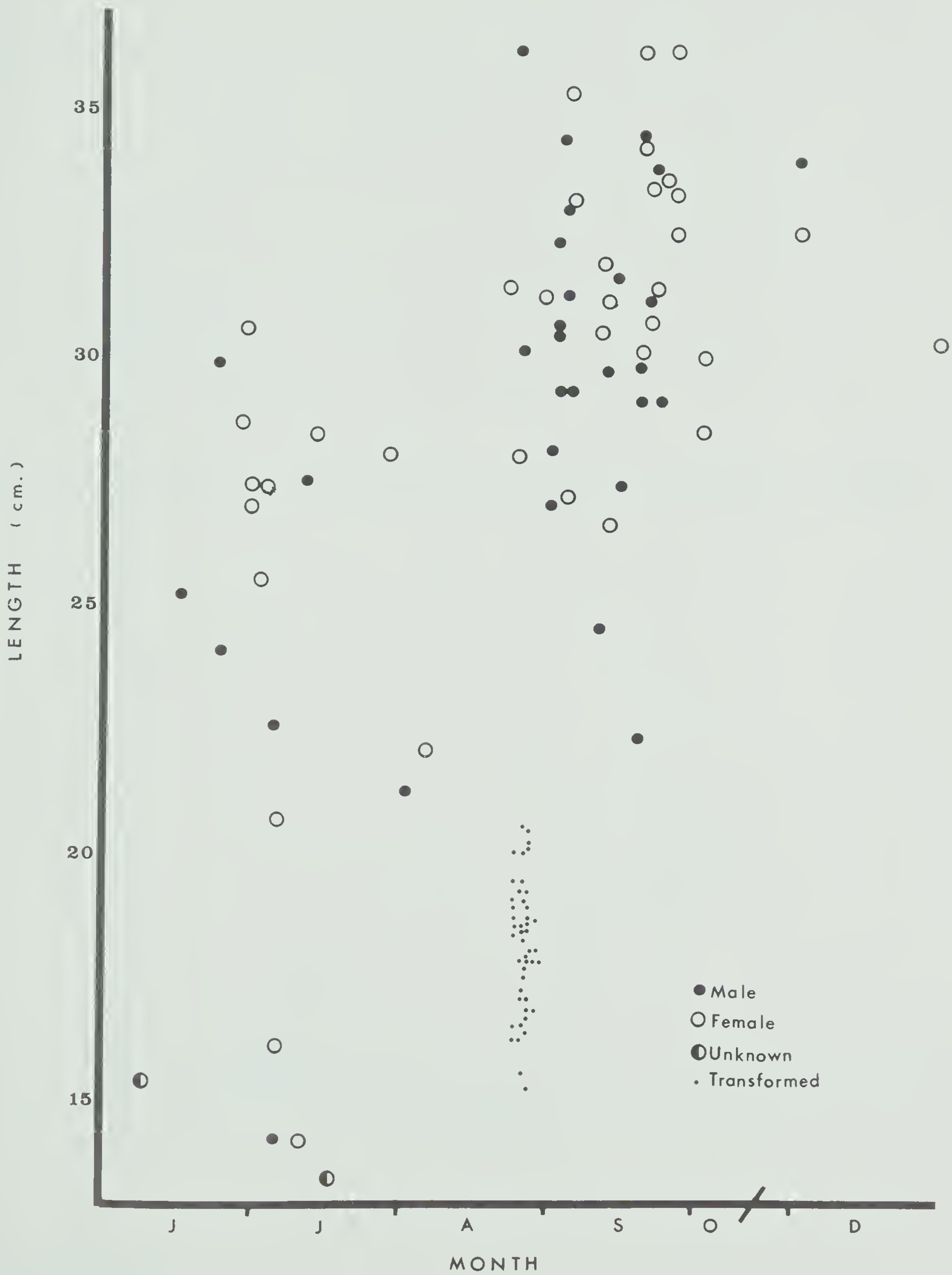
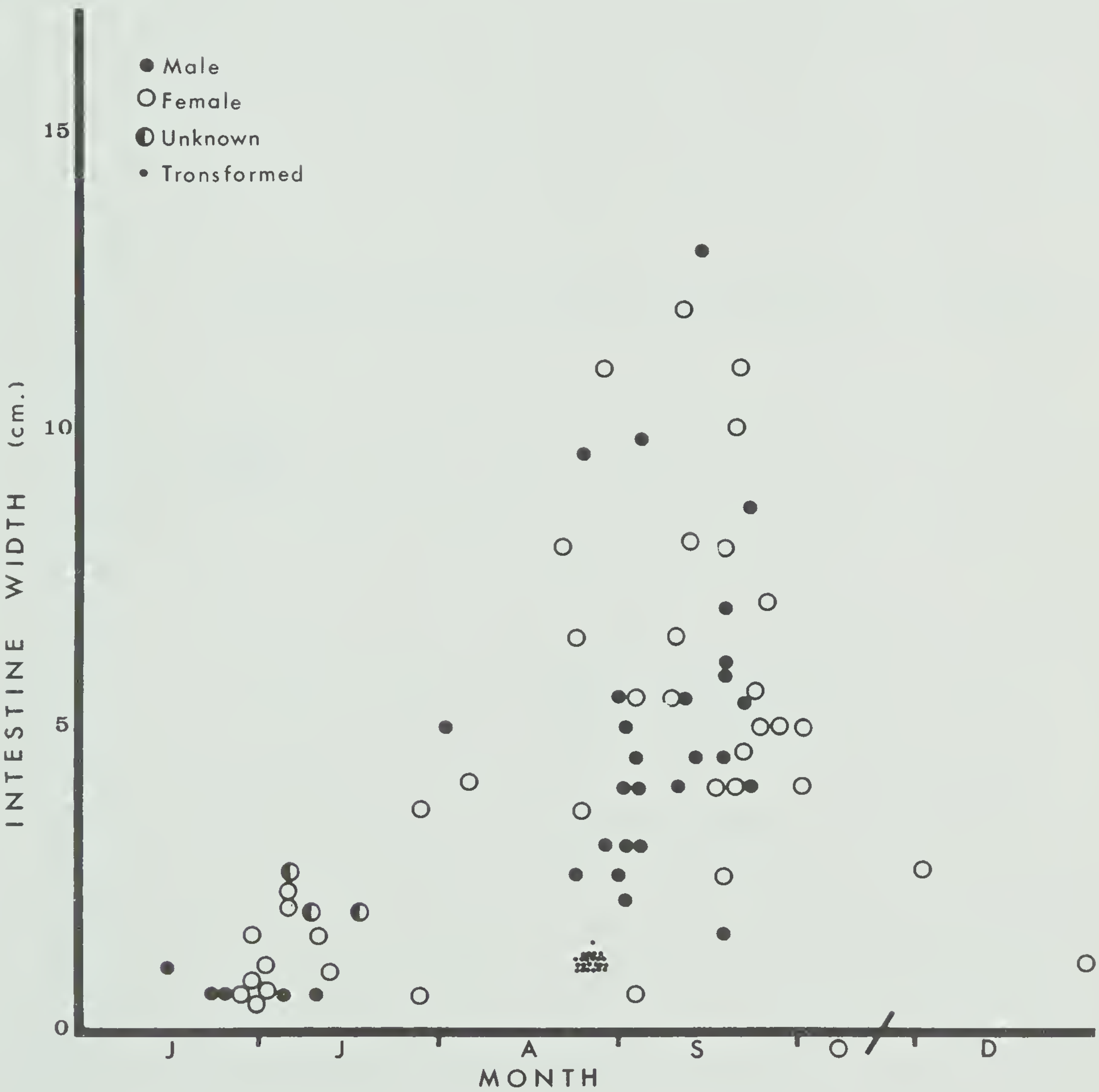
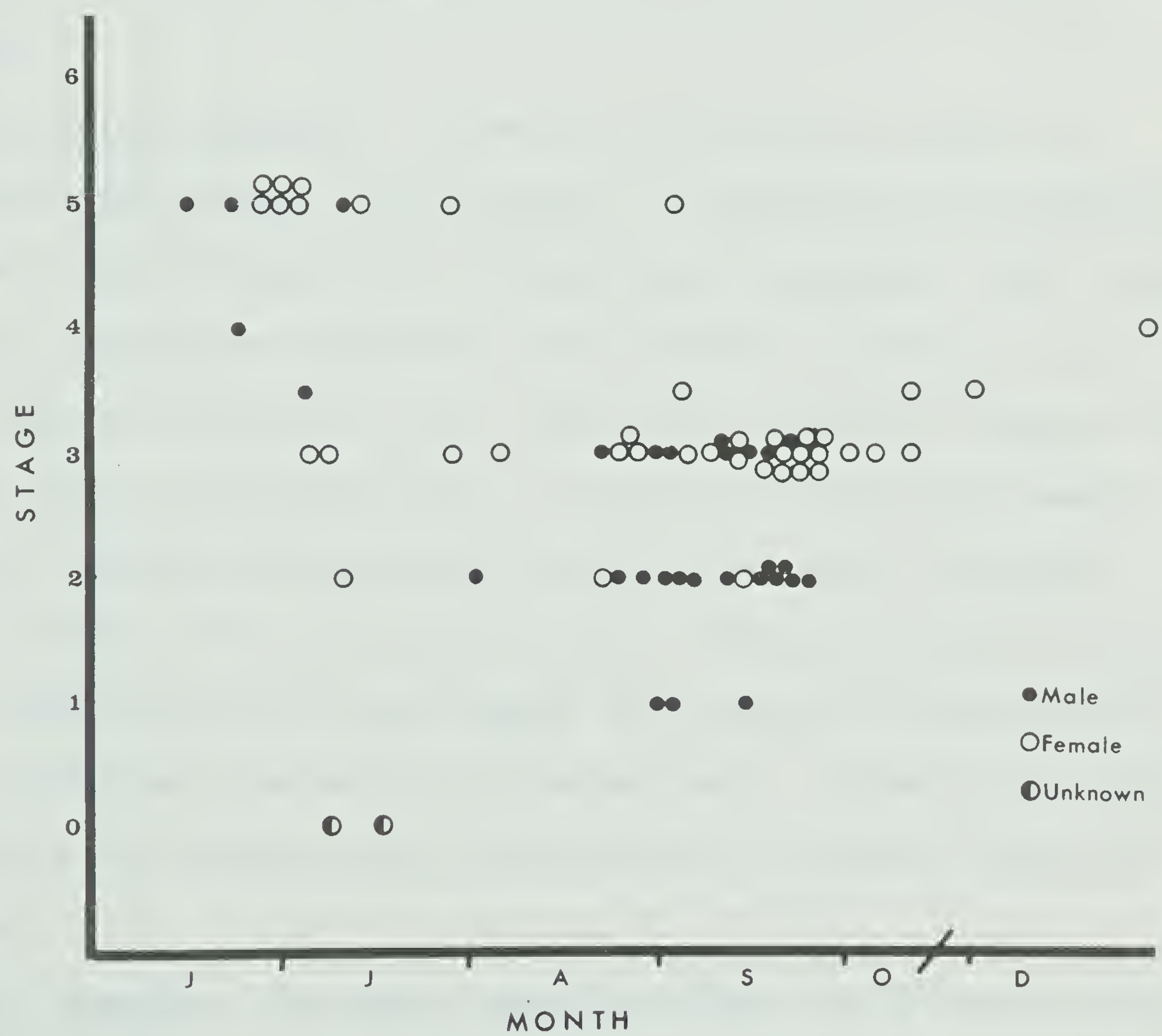

LENGTH (cm.)
35
30
25
20
15
J
J
A
S
O
D
MONTH
Male
Female
Unknown
Transformed

Figure 10. *Seasonal distribution of intestine width in adult lampreys.*



Male
Female
Unknown
Tronsformed
15
10
5
0
INTESTINE WIDTH (cm.)
J
J
A
S
O
D
MONTH

Figure 11. *Adult sexual state at time of capture.*



STAGE
6
5
4
3
2
1
0
J
J
A
S
O
D
MONTH
Male
Female
Unknown

also records spent males between June 1 and June 16. It is possible that the Hay River trap nets were in too late to catch migrating adults.

An attempt on June 26, 1967 to determine if adults were moving upstream in the Hay River at night was unsuccessful. The West Channel was closed off from 2030 until 0130 with an electrical barrier. Only fish were seen attempting to escape.

On July 6, 1967 a search of the river bottom below Louise Falls revealed nothing. The search was made by two people using skin diving equipment. It lasted approximately three hours.

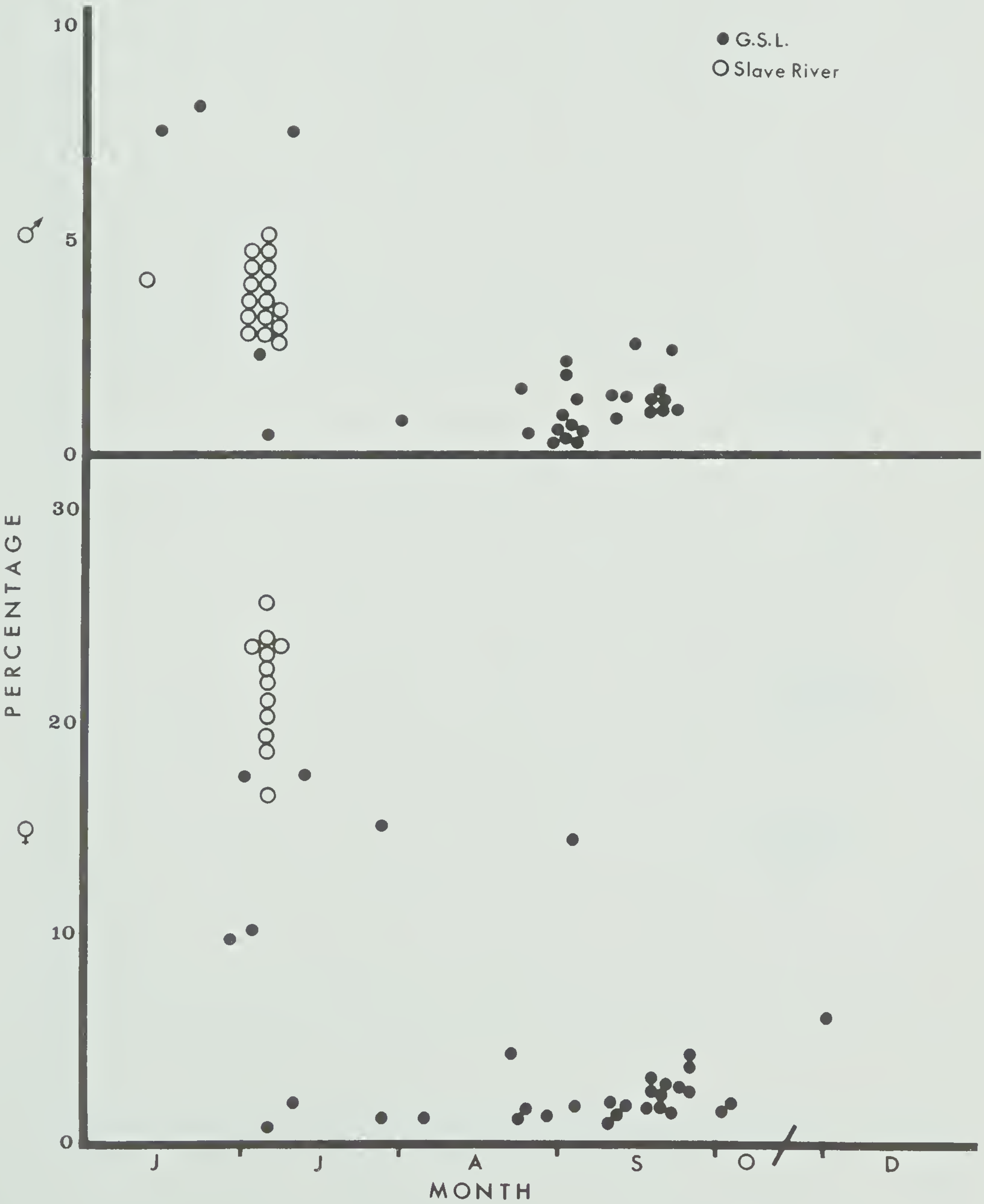
Ammocoetes may be taken on the Hay River as far upstream as mile 20. Hence some spawning must occur between there and Louise Falls. Unfortunately this area is virtually inaccessible to investigators with shocking equipment.

2. Sexual condition. The sexual condition of all adults was described using Vladykov's (1961) method. A progression occurs from zero when sex is not distinguishable, through four, a prespawner, five, a spawner, and six, a postspawner (Figure 11). Also consider the change of gonad weight with time (Figures 12, 13). These later figures also suggest June or early July as the spawning time. It would be expected that immature or newly transformed lampreys would not show much sexual development. Figure 14 shows this is not always the case. The advanced state of some of the females especially would suggest the existence of a non-parasitic lamprey (Hubbs and Trautman 1937; Zanandrea 1961). Ultimate proof would be the finding of a sexually mature ammocoete but this was not seen in 75 examined.

3. Fecundity. Egg counts ranged from 9790 to 29,780 with a mean of 21,415 (Table 2). In part A both anterior and posterior regions of the ovary were used in order to see if discrepancies in number would occur.

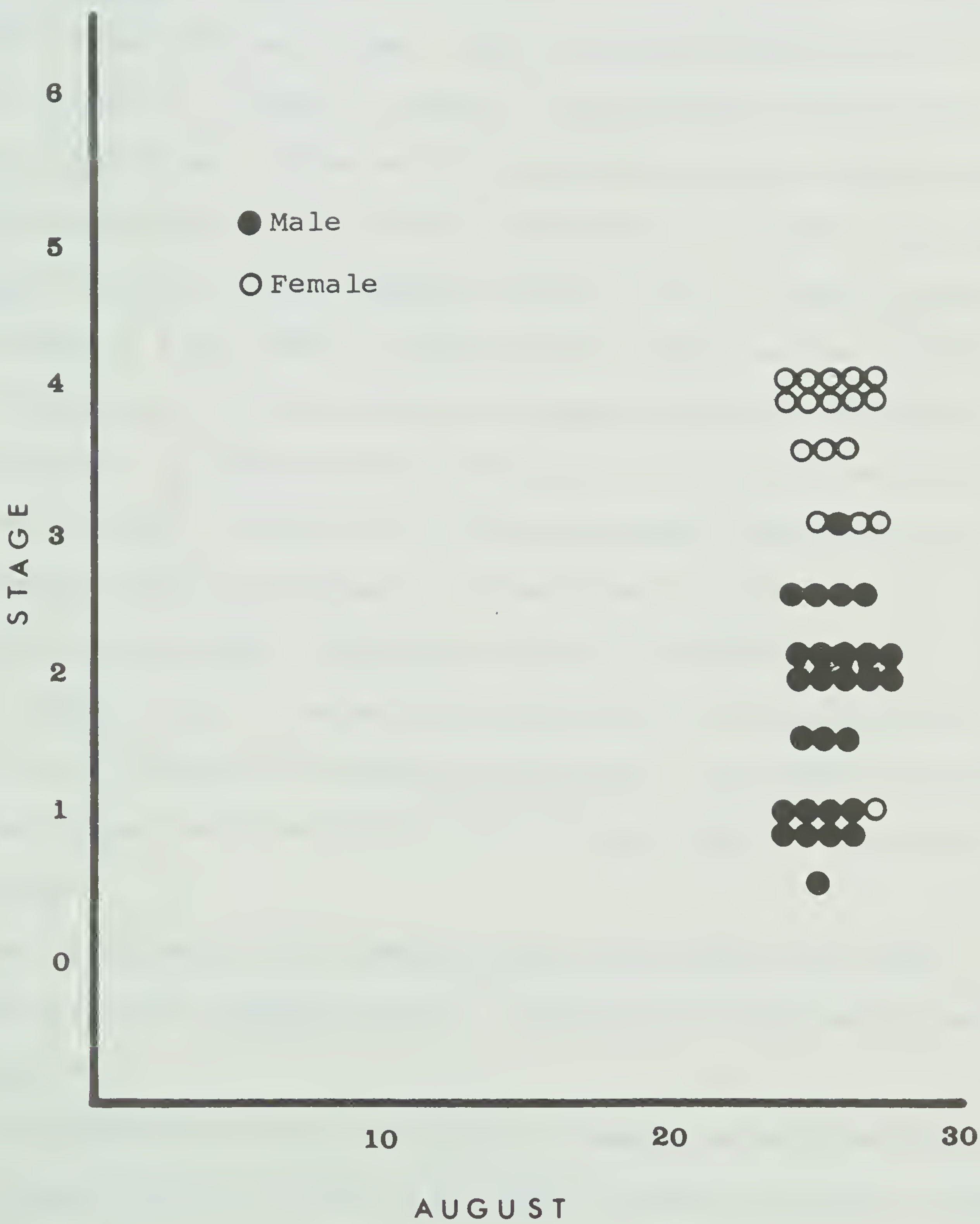
Figure 12. *Male testis weight, as a percentage of total body weight, at time of capture.*

Figure 13. *Female ovary weight, as a percentage of total body weight, at time of capture.*



G.S.L.
Slave River
10
5
0
30
20
10
0
♂
♀
PERCENTAGE
J
J
A
S
O
D
MONTH

Figure 14. *Sexual state of newly transformed lampreys.*



Male
Female
STAGE
6
5
4
3
2
1
0
10
20
30
AUGUST

This was not the case; hence, the remaining values were based on a single count. Berg (1931) states that *Lampetra japonicus septentrionalis* has approximately 25,000 eggs and that *Lampetra japonicus kessleri* has few, but gives no absolute values. The *septentrionalis* value is quite comparable to the Great Slave mean of 21,415.

D. Ammocoetes

1. Habitat. Ammocoetes are usually collected from small backwaters or eddies along the river's edge. A good location on the Hay River is shown in Figure 15. Current is generally slight and the bottom usually consists of soft mud. Seldom are larvae taken from a sand or gravel bottom. Tremendous concentrations may occur if conditions are suitable. For example, on August 25, 1967, 383 were captured from bed 6 in a 137 minute period. Many escaped as I was unable to capture them as rapidly as they appeared.

Conditions in the Slave River are somewhat different than those in the Hay River. All ammocoetes were collected in the Slave River from the extreme river edge, for there is a very rapid dropoff, making shocking while wading somewhat precarious. In some places the main channel is over 100 feet deep. Mud beds, comparable to those in the Hay River, do not seem common along the shore. Generally the area shocked was intercombed with deadfalls and frequently the bottom was quite hard. The ammocoetes tended to be much paler than those from the Hay River and seemed to show a pale green tinge.

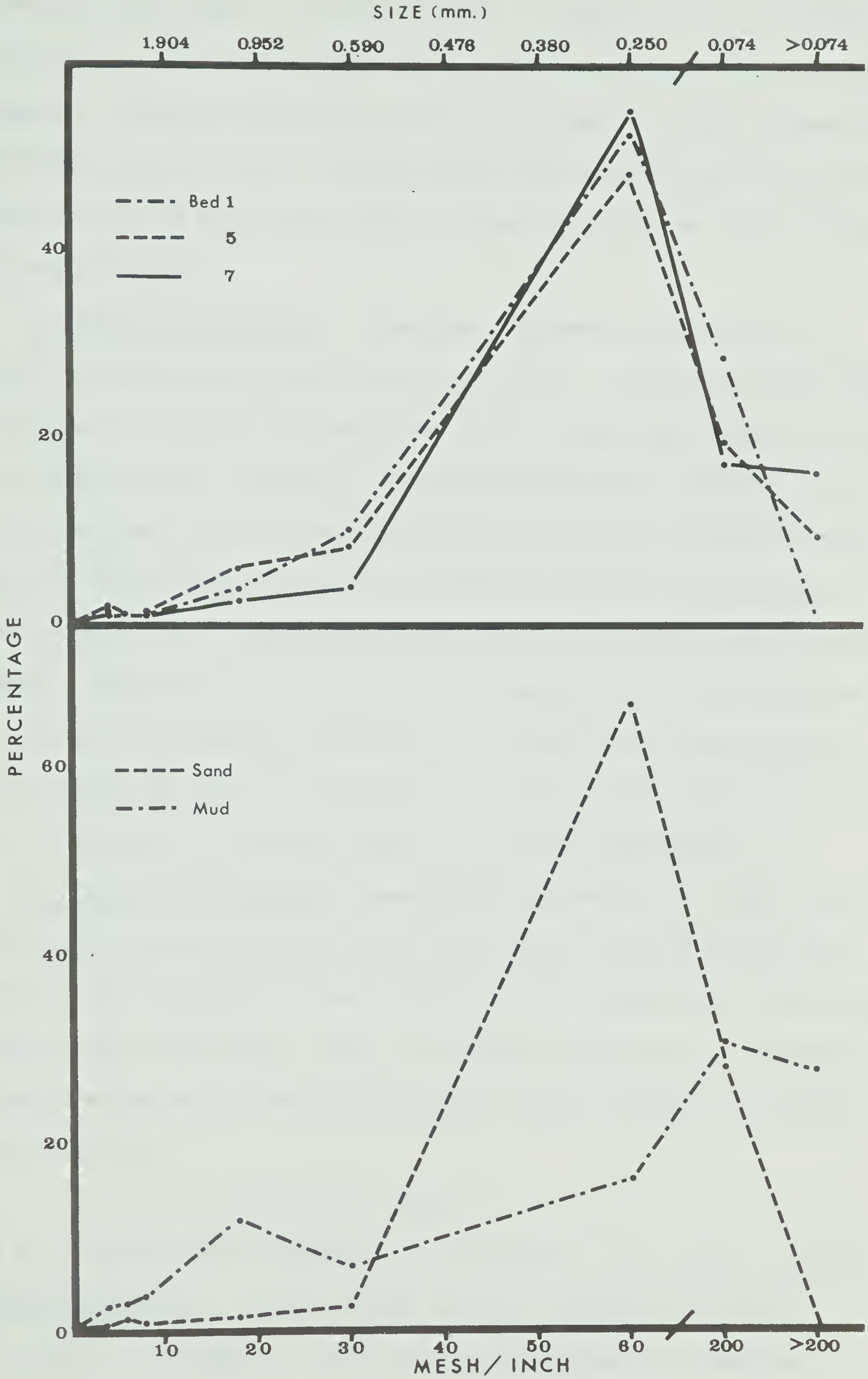
Mud conditions of three ammocoete beds from the Hay River were determined with U.S. Standard Sieves. The results are expressed as percentages in Figure 16.

An aquarium was set up to determine if ammocoetes preferred sand or mud. A glass partition was put in the middle, thereby preventing a mixture

Figure 15. *Bed 7 on the Hay River.*

Figure 16. *Particle composition of three ammocoete beds on the Hay River.*

Figure 17. *Particle composition in aquarium used for mud-sand preference test.*



SIZE (mm.)
1.904
0.952
0.590
0.476
0.380
0.250
0.074
>0.074
Bed 1
5
7
40
20
0
PERCENTAGE
Sand
Mud
60
40
20
0
10
20
30
40
50
60
200
>200
MESH/ INCH

of the sand and the mud. On July 17, 1967, 33 ammocoetes were introduced at the midline. On July 27, 1967, 23 were in the mud and 10 in the sand. On August 2, 29 were in the mud and four in the sand. Figure 16 shows the composition of the strata. It can be seen that particle size is far more uniform in the mud than in the sand. The sand however more closely reflects the river situation.

2. Ammocoete movements. Downstream movement of ammocoetes is usually considered to be passive with the current. Ammocoetes which swam into the main current of the Hay River, while escaping shocking, were not able to make progress against it. It was interesting to see that none of the specimens marked was recaptured anywhere but in its original location. Ammocoetes kept in aquaria during the summer of 1967 were never seen to leave the mud. After August 1st, however, two newly transformed lampreys appeared. Frequently they would lie on the mud surface in the aquarium.

The Hay River trapnets did pick up ten ammocoetes between June 3, 1967 and August 9, 1967. It is obvious that some free movement must occur, but it is difficult to determine when or over what distances.

3. Population estimates. Ammocoetes from beds 2, 3, 5 and 7 were marked. In each case the marking was done within a period of five days (Table 3). The technique was not difficult and the ammocoetes were usually released within a few hours. Only 4.5 per cent recapture was obtained. Population estimates are based upon Bailey's (1951) formula from Ricker (1958). This is:

$$N = M(C+1) \;/\; R+1$$

where N is the population number, C is the number in the sample and R is the number recaptured. Table 4 shows when the recaptures occurred.

At bed 7, on August 26, 1967 an attempt was made to determine ammocoete density by counting the number of ammocoete holes visible after

Figure 18. *An ammocoete burrow in an aquarium.*

Table III. *Population estimates for beds 2, 3, 5 and 7 and for the entire Hay River.*

Table IV. *Time of recapture for 21 marked ammocoetes.*

Bed No.	Date marked	No. marked	Total captured	recaptured	population estimate
2	May 24-28	83	85	0	-----
3	May 26-30	157	276	4	3,768
5	July 3-4	113	543	9	4,870
7	June 21	110	187	8	953

Combined estimate for beds 2, 3, 5 and 7 - 13,238
Combined estimate for entire Hay River - 27,927

Date	Bed Number 2	3	5	7	Total
June 1 to 15		4			4
June 16 to 30			5	8	13
August 1 to 15					0
August 16 to 31			4		4
	0	4	9	8	21

water levels had receded. Figure 18 shows a burrow in an aquarium. Six square metres were counted yielding 284, 188, 38, 111, 89 and 114 holes per square metre for an average value of 137.

E. Ammocoete growth and length-frequency distributions

1. Length-frequency distributions. As lampreys cannot be aged by standard fishery techniques, length-frequency distributions are often used as an indicator. To be considered here are 3,076 ammocoetes.

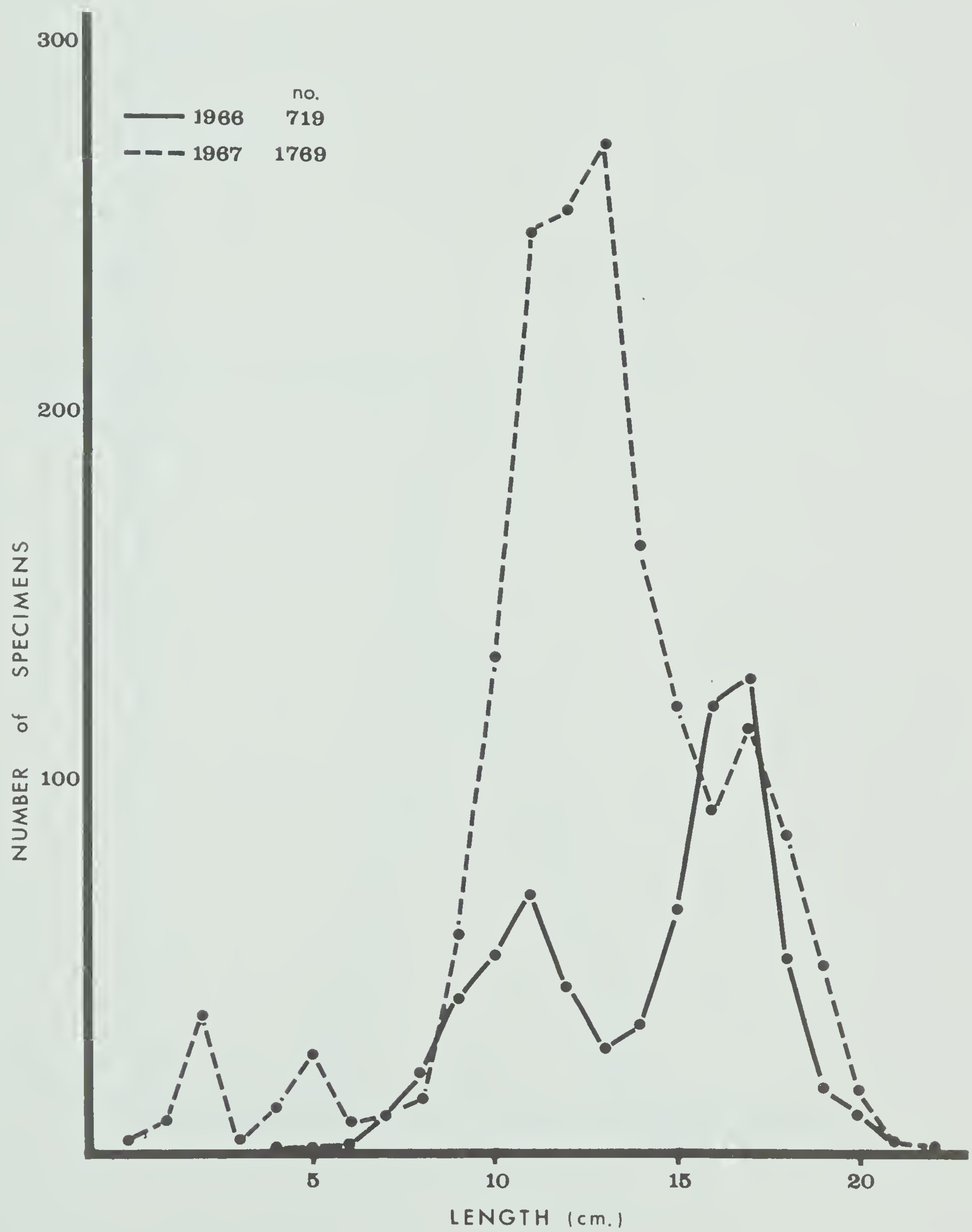
Hay River collections, when sorted by bed and time period, show some interesting results. Due to the number taken those from beds 1, 3, 4 and 5 are best suited for examination. With regard to these beds it must be remembered that a population sampled represents that population minus those previously removed. Also, electroshocking selects for larger ammocoetes. This is shown in several ways: a) small ammocoetes cannot be stopped by the electrical field, b) the length-frequency distributions are noticeably lacking in small ammocoetes.

Plotting the total of the Hay River length data (Figure 19) suggests the existence of four peaks and hence, four age classes. We were particularly fortunate in spotting the small ammocoetes during 1967. The age classes from the graph may be artificially selected as follows:

Year	Length
1	0 to 3.5 cm
2	3.0 to 8.0 cm
3	7.5 to 15.5 cm
4	15.0 to 22.0 cm

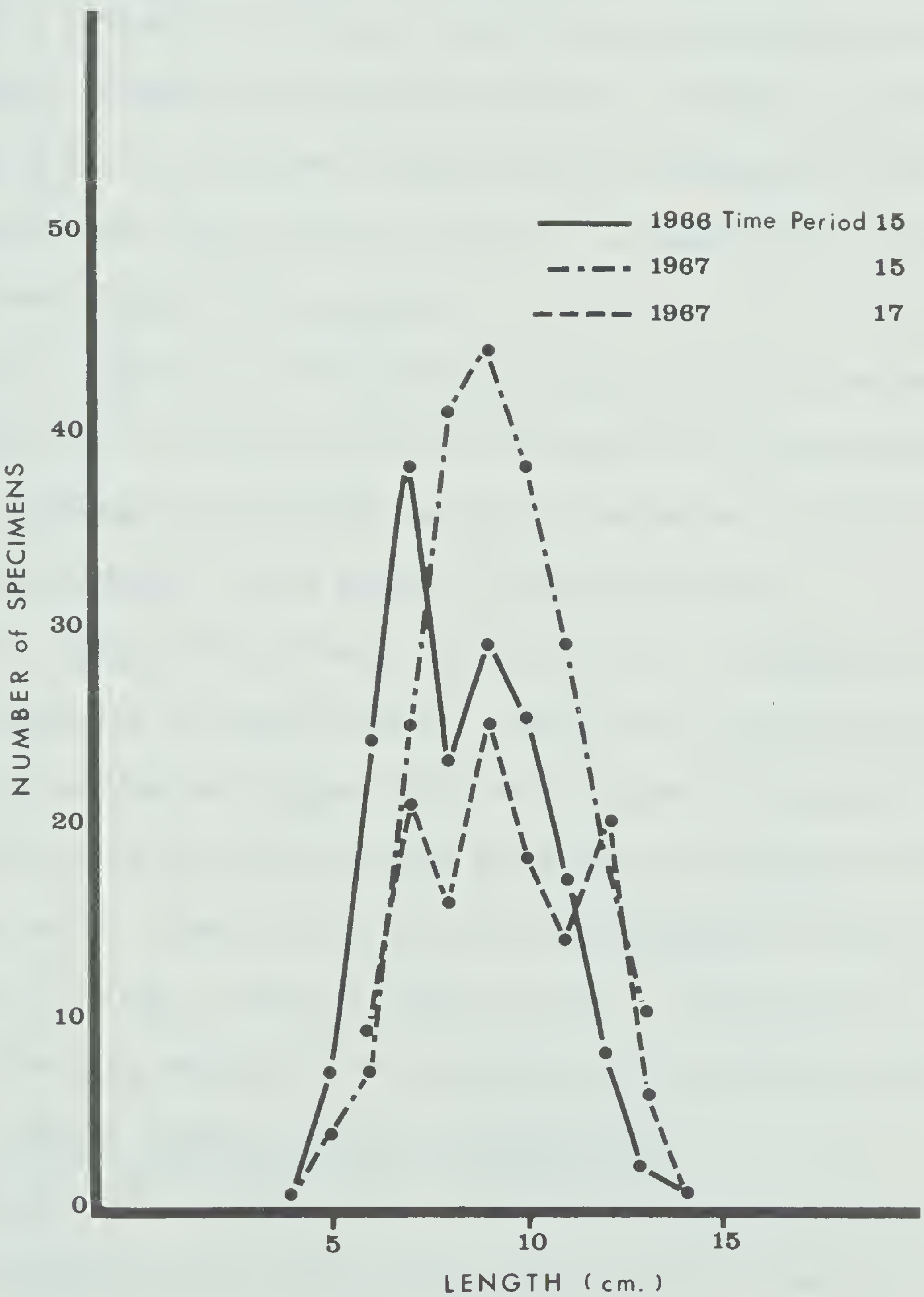
Slave River distributions (Figure 20) are more difficult to interpret, possibly because all collections are from the delta region and hence likely represent only one or two age classes. The 1966 collection suggests two

Figure 19. *Length-frequency distribution of ammocoetes for the Hay River during 1966 and 1967.*



300
200
100
NUMBER of SPECIMENS
no.
1966 719
1967 1769
5
10
15
20
LENGTH (cm.)

Figure 20. *Length-frequency distribution of ammocoetes from the Slave River during 1966 and 1967 summers.*



1966 Time Period 15
1967 15
1967 17
NUMBER of SPECIMENS
0
10
20
30
40
50
5
10
15
LENGTH (cm.)

modes but this is not reflected in the 1967 time period 15 data. A transformation size of approximately 14.0 centimetres is suggested. Two of this size were taken in 1967 during September. Certainly specimens of less than 40 millimetres must be present upstream. There is no question that SlaveRiver ammocoetes are consistently smaller than those from the Hay River.

a. Specific ammocoete beds in the Hay River.

Bed 1 (Figure 21): Two age classes are represented later in the summer. Growth has occurred in the 16.0 centimetre specimens and apparently 12.0 centimetre ammocoetes have immigrated from upstream between time periods 13 and 16. By time period 16 newly transformed lampreys are appearing.

Bed 3 (Figure 22): The ammocoetes larger than 13.0 centimetres have moved out of the bed and may be included in the immigrants in bed 1. Although the distribution here is essentially normal the range would suggest two or possibly three age classes.

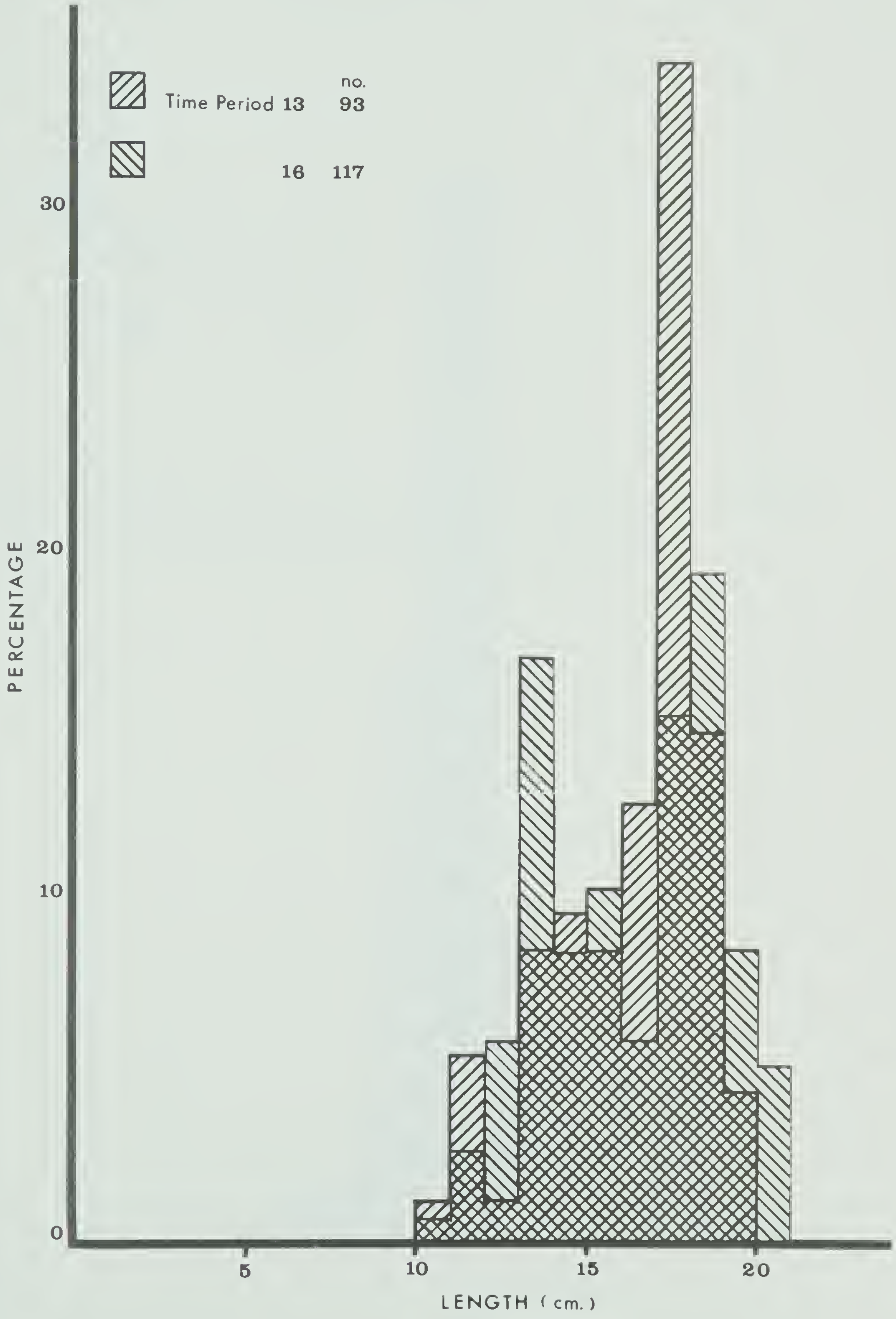
Bed 5 (Figure 23): Of most interest here is the appearance of small ammocoetes in time period 16. These likely come from upstream.

The above information suggests that as the summer progresses the larger ammocoetes move out of the upstream beds and begin to congregate in the beds near the river mouth. There is not quite so much movement in the three-year-old ammocoetes, although a few also appear at bed 1. While this is happening the yearling ammocoetes are appearing at the upstream beds.

b. Specific time periods in the Hay River.

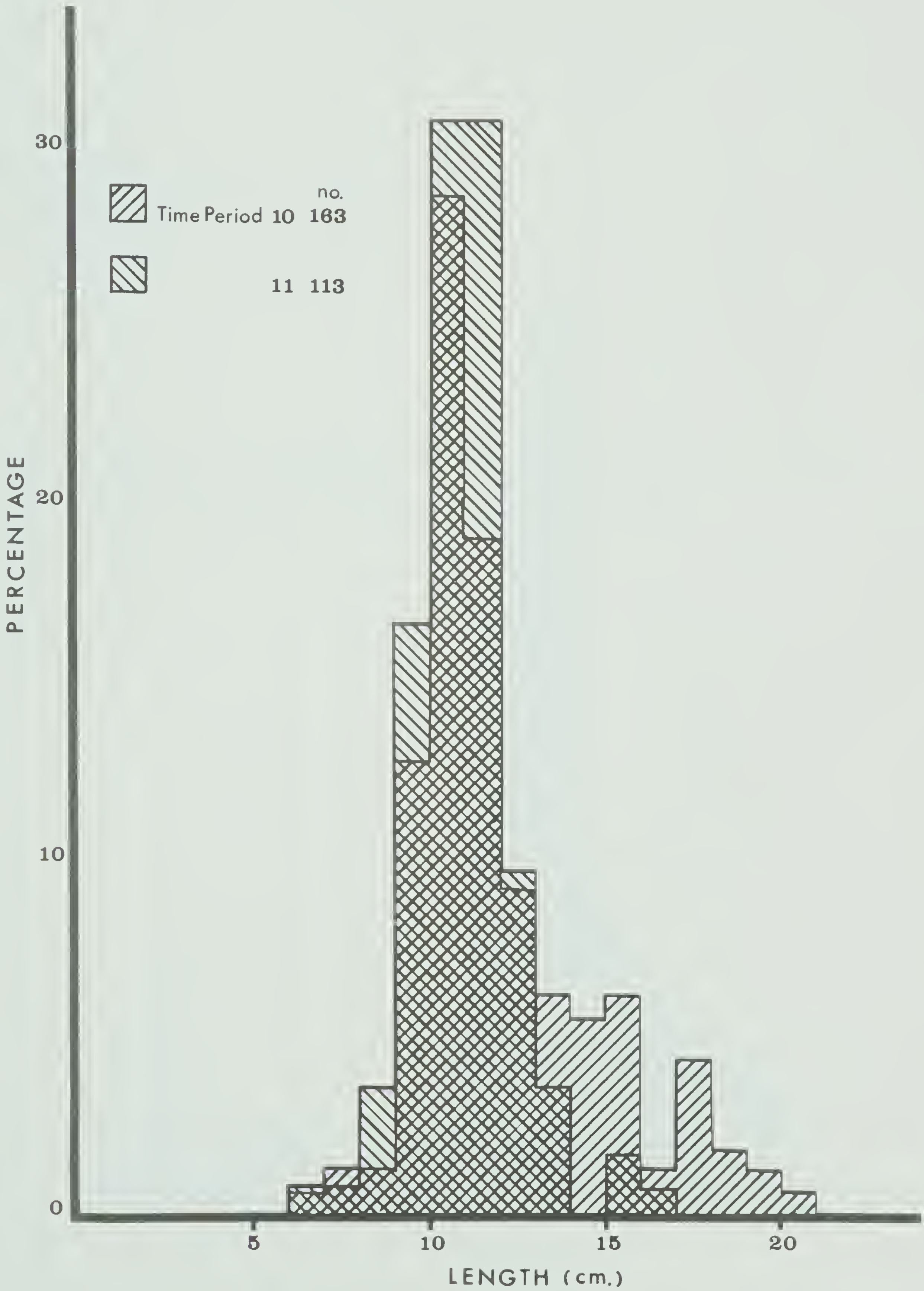
Time period 13 (Figure 24): It is at once apparent that the larger ammocoetes are closer to the river mouth and that at least two age classes are present even though one may be predominant.

Figure 21. *Relative numbers of ammocoetes of different lengths in bed 1, Hay River, during time periods 13 and 16, 1967.*



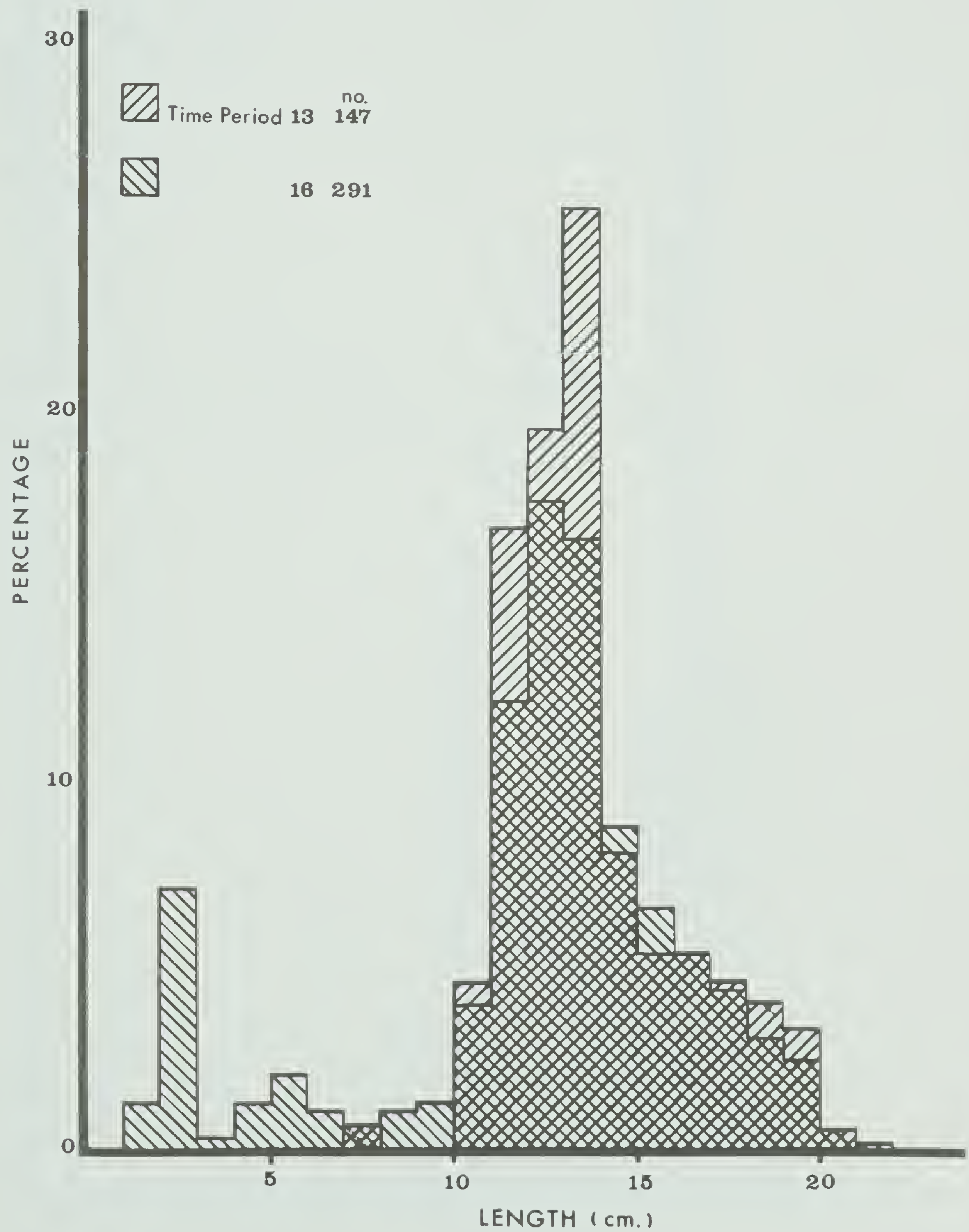
no.
Time Period 13 93
16 117
30
20
10
0
PERCENTAGE
5
10
15
20
LENGTH (cm.)

Figure 22. *Relative numbers of ammocoetes of different lengths in bed 3, Hay River, during time periods 10 and 11, 1967.*



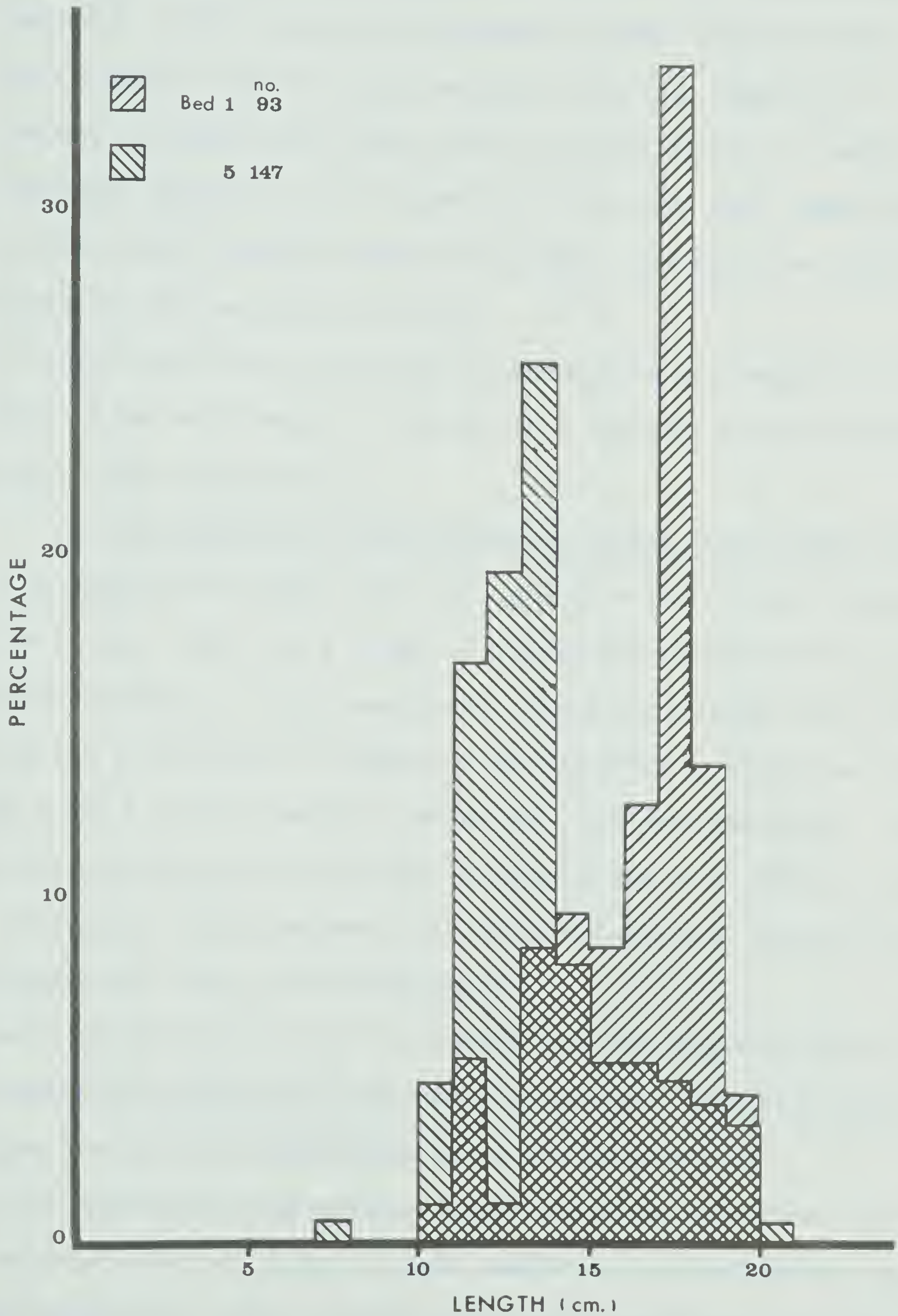
PERCENTAGE
30
20
10
0
no.
Time Period 10 163
11 113
5
10
15
20
LENGTH (cm.)

Figure 23. *Relative numbers of ammocoetes of different lengths in bed 5, Hay River, during time periods 13 and 16, 1967.*



30
20
10
0
PERCENTAGE
no.
Time Period 13 147
16 291
5
10
15
20
LENGTH (cm.)

Figure 24. *Relative numbers of ammocoetes of different lengths during time period 13, 1967, for beds 1 and 5, Hay River.*



no.
Bed 1 93
5 147
30
20
10
0
PERCENTAGE
5
10
15
20
LENGTH (cm.)

Time period 16 (Figure 25): A bimodality is apparent in bed 1. Bed 5 especially seems to have all ages of ammocoetes. Beds 4 and 5 are within one half mile of each other, which likely explains their similarity. Peaks below 11.0 centimetres are more important for their existence than for their amplitude, for they suggest the presence of younger age classes that are more difficult to sample. Especially important is the appearance of the very small ammocoetes, as they likely represent young of the year. Once again the larger ammocoetes are near the river mouth.

It can be seen that as the summer progresses the age composition of the inhabitants of the beds changes. Time period 16 includes a more complicated bed structure than time period 13.

c. <u>All beds for all time periods in the Hay River (Figure 26).</u>

It is apparent that beds 4 and 5 are quite similar and hence shall be considered as one. Bed 1 has a primarily bimodal distribution and contains the highest percentage of large ammocoetes. Bed 3 has a small fourth year population but is difficult to compare as the bed dried up after time period 11. Beds 4 and 5 contain yearling, second and third year ammocoetes. The low peak for one and two year olds must be largely due to collection technique. Figure 9 indicates that transformed size seldom exceeds 20.0 centimetres and that shrinkage does occur with metamorphosis.

Hence, the beds nearest the river mouth have the largest ammocoetes and the number here increases as the summer progresses. Generally population composition here is not as complicated as in the upstream beds.

In the upstream beds immigration downstream occurs throughout the summer and in mid-July an influx of small ammocoetes is occurring from some upstream spawning area. Most of these beds contain ammocoetes of several age classes.

Figure 25. *Relative numbers of ammocoetes of different lengths during time period 16, 1967, for beds 1, 4 and 5, Hay River.*

30
20
10
0
PERCENTAGE
no.
Bed 1 117
4 370
5 291
5
10
15
20
LENGTH (cm.)

Figure 26. *Relative numbers of ammocoetes of different lengths for beds 1, 3, 4 and 5 on the Hay River, 1967 summer.*

no.
Bed 1 243
3 276
4 370
5 543
30
20
10
0
PERCENTAGE
5
10
15
20
LENGTH (cm.)

2. Growth study. On July 26 and 27, 1967, 74 ammocoetes were measured under the anaesthetic MS 222, color coded for length (Figure 27), and placed into a bottomless box in the Hay River. The box had wire mesh openings on the sides, was sealed on top and was driven eight to ten inches into the mud.

The mean length of the ammocoetes introduced was 16.1 centimetres. On August 21, 1967 the ammocoetes were removed and measured again. They averaged 3.5 millimetres shorter than when put in. After being killed with formaldehyde they were again measured on August 22. They averaged 2.3 millimetres shorter than when measured under anaesthesia. A repeat measurement on January 26, 1968 gave an average difference of less than one millimetre when compared to the August 22nd measurements.

I have no reason for the decrease in length which occurred.

F. Meristics, morphometry and pigmentation

All measurements were made on preserved specimens, using dividers and a metal ruler. Tooth characters are restricted to adults.

1. Meristic counts.

a) Trunk Myomeres.

Lindsey and McPhail (1968) give myomere counts for Arctic Lamprey from the Mackenzie (68-74, mean 72.0). These values are essentially the same as those obtained from 671 lampreys from the Great Slave Lake region (Table 5).

2. Morphometry.

a. Teeth.

Figure 28 illustrates the dentition of this species. The terminology is based upon Vladykov and Follett (1967). Table 5 gives a summary of the results.

Figure 27. *Ammocoete colour coded for length between 186 and 190 millimetres.*

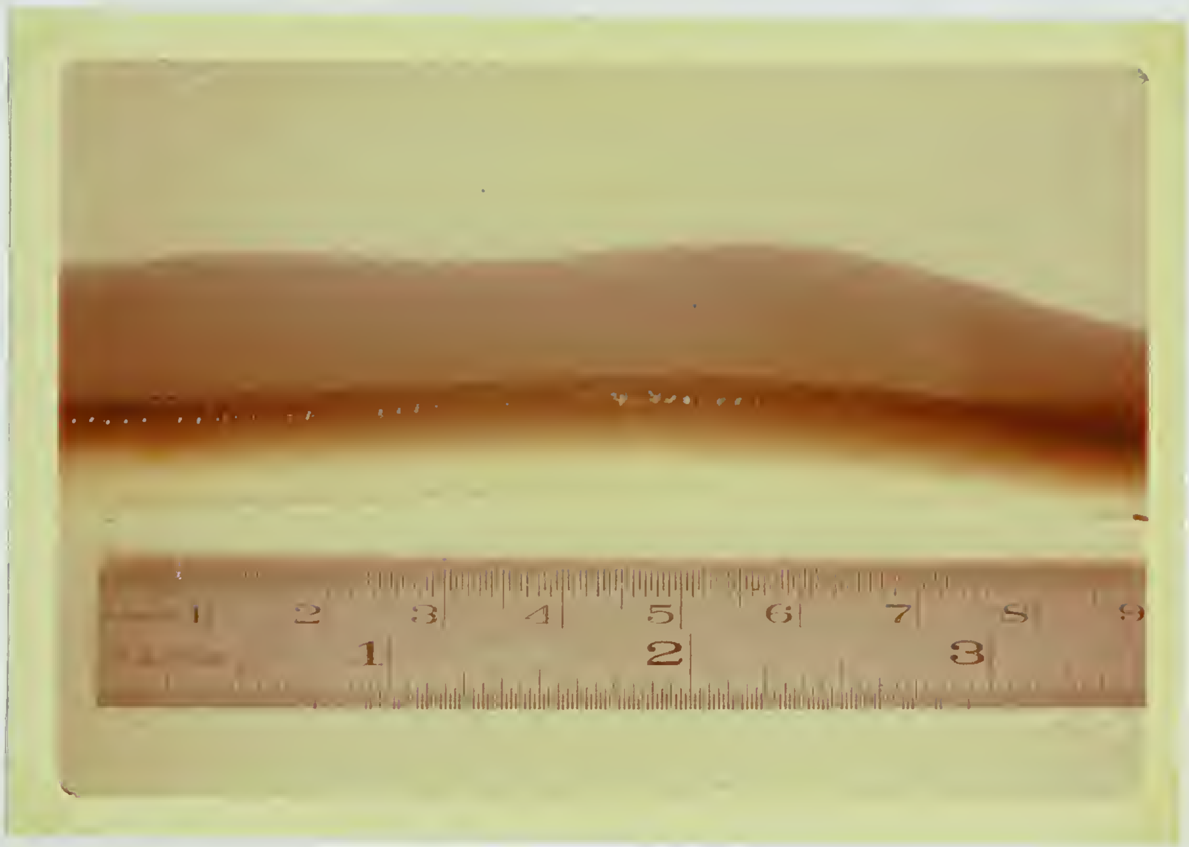


Table V. *Trunk myomeres*

	AMMOCOETES Hay River	AMMOCOETES Slave River	TRANSFORMED Hay River	TRANSFORMED Great Slave	ADULTS Slave River
range	60-74	64-76	65-73	66-77	65-74
mean	70.1	70.6	69.5	72.0	70.7
S.D.	1.7	2.0	1.7	2.2	2.5
No. examined	354	175	49	62	31

Infraoral lamina - mean dimensions (mm) and mean number of cusps

Area	Sex	Distance between most lateral cusps (T)	Base(B)	T/B	Cusps	Number examined
SR	♀	4.9(4.4-5.5)	6.4(6 0-7.3)	0.8(0.68-0.84)	8.3(8-9)	12
SR	♂	5.3(4.5-6.0)	6.3(5.5-7.2)	0.8(0.77-0.91)	8.2(8-9)	19
GSL	♀	4.5(2.6-6.0)	5.8(3.5-7.5)	0.8(0.43-0.98)	8.1(8-9)	39
GSL	♂	4.5(2.6-6.0)	5.8(3.4-7.0)	0.8(0.66-0.90)	8.3(8-10)	32

Transverse lingual lamina - mean base width (mm) and mean number of cusps.

Area	Sex	Cusps	No. examined	Width	No. examined
SR	♀	12.1(9-16)	10	3.0(2.6-3.4)	10
SR	♂	12.9(9-15)	14	3.2(2.4-3.9)	19
GSL	♀	14.7(9-18)	35	3.6(2.0-4.6)	34
GSL	♂	14.5(9-18)	30	3.8(2.2-5.0)	30

Endolaterals.

-all 31 Slave River specimens had 6 bicuspid teeth

-76 Great Slave Lake specimens had 6 bicuspid teeth

- 1 Great Slave Lake specimen had posterior endolaterals unicuspid.

Anterials - mean number of teeth

Area	Sex	Teeth	No. examined
SR	♀	19.1(17-23)	11
SR	♂	19.1(17-22)	16
GSL	♀	19.0(16-24)	37
GSL	♂	19.7(15-25)	33

Posterials - mean number of teeth

Area	Sex	Teeth	No. examined
SR	♀	14.2(10-17)	12
SR	♂	14.4(12-21)	19
GSL	♀	17.1(11-23)	36
GSL	♂	18.0(13-23)	31

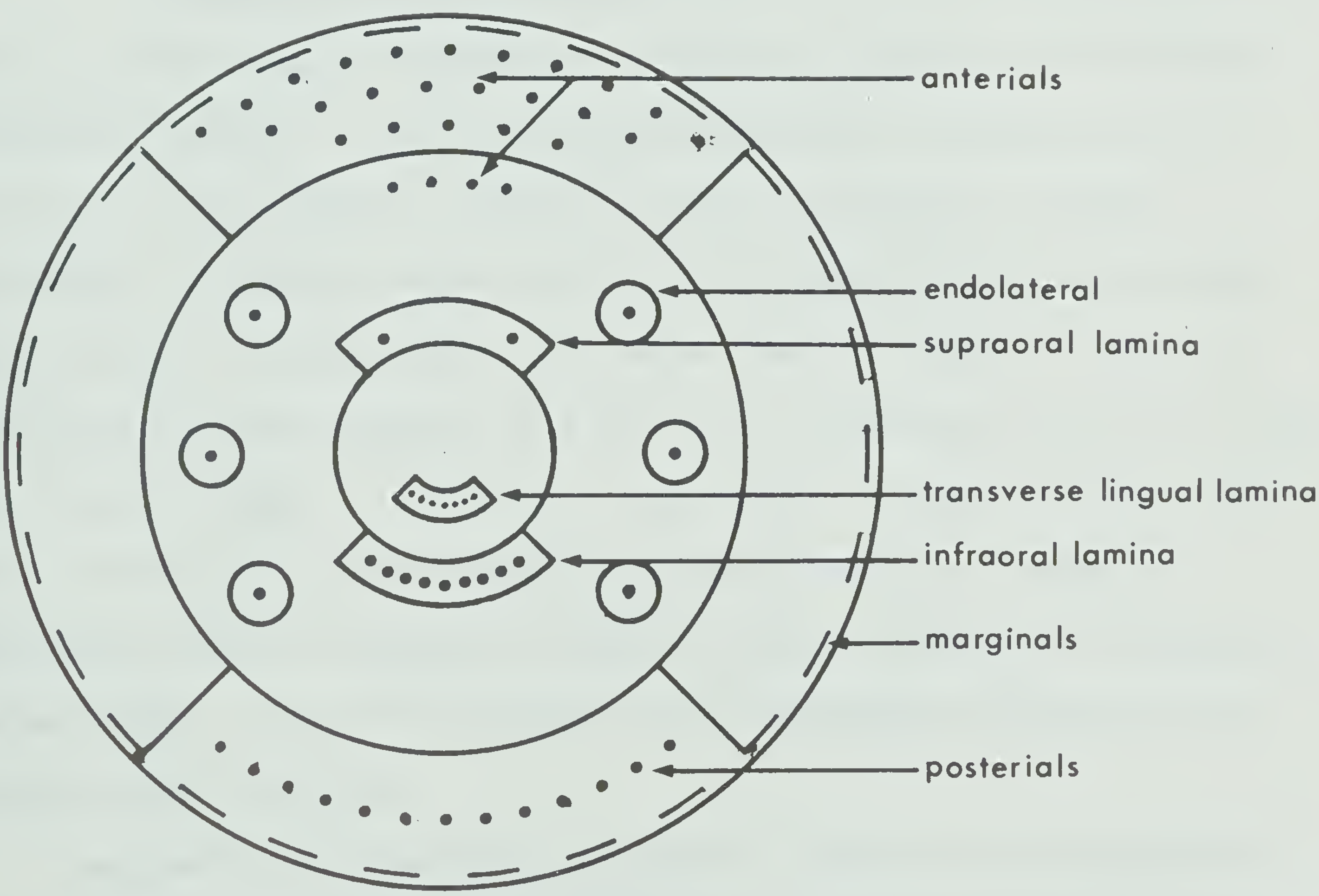
Marginals - mean number of teeth

Area	Sex	Teeth	No. examined
SR	♀	59.6(55-65)	8
SR	♂	63.2(58-71)	12
GSL	♀	63.5(54-71)	32
GSL	♂	64.2(53-75)	29

Supraoral lamina mean dimensions (mm) and mean number of cusps

Area	Between cusps (T)	Base (B)	T/B	S.D.	bicuspid	tricuspid
SR	3.2(2.5-5.0)	5.7(5.0-6.8)	0.6	0.05	75	1
GSL	2.8(1.4-3.5)	5.3(3.0-7.0)	0.5	0.06	31	

Figure 28. *Adult dentition of Lampetra japonica.*


anterials
endolateral
supraoral lamina
transverse lingual lamina
infraoral lamina
marginals
posterials

Tooth characters cannot be compared between Great Slave Lake and Slave River specimens, as the latter are in spawning condition and hence have blunt teeth.

Anterials are considered to be of little taxonomic value (Lindsey and McPhail 1968; Vladykov and Follett 1967). Posterials are frequently used in keys but their use as a generic character has recently come into dispute (Lindsey and McPhail 1968). Only in this character does any difference appear between Great Slave and Slave River specimens.

Dentition suggests the existence of only one species in the study area.

b. Regression analysis

Regression lines were calculated for a series of characters in order to relate length (independent variable) to some part of the animal (dependent variable). This relationship represents the growth rate of the part. Both values are expressed and were calculated as natural logarithms. A positive slope of the line (b) greater than one indicates that the part is increasing in size faster than the length. A positive slope less than one indicates that the part is increasing in size at a rate less than the length. If the parts size remains constant then the slope is zero. If the part is decreasing in size then the slope is negative. Characters used are indicated in Figure 29 and are described by Hubbs and Lagler (1958). It can be seen that not all characters were used in all stages of the life cycle.

Included in the equations represented in Table 6 are 531 ammocoetes, 55 transformed (immature adults) and 109 adults. Four hundred and eleven are from the Hay River, 206 from the Slave River and 78 from Great Slave Lake.

Table 6 shows that growth is occurring in both Hay River and Slave River ammocoetes. Generally the growth rate (b) is higher in the Hay River. This

Figure 29. *Measurements made on preserved specimens.*

B-body depth, BR-branchial length, C-caudal fin depth, D-height of second dorsal fin, DB-dorsal fin base, H-horizontal diameter of eye, O-oral disc, P-postorbital, PB-prebranchial, PD-predorsal, S-snout, T-tail.

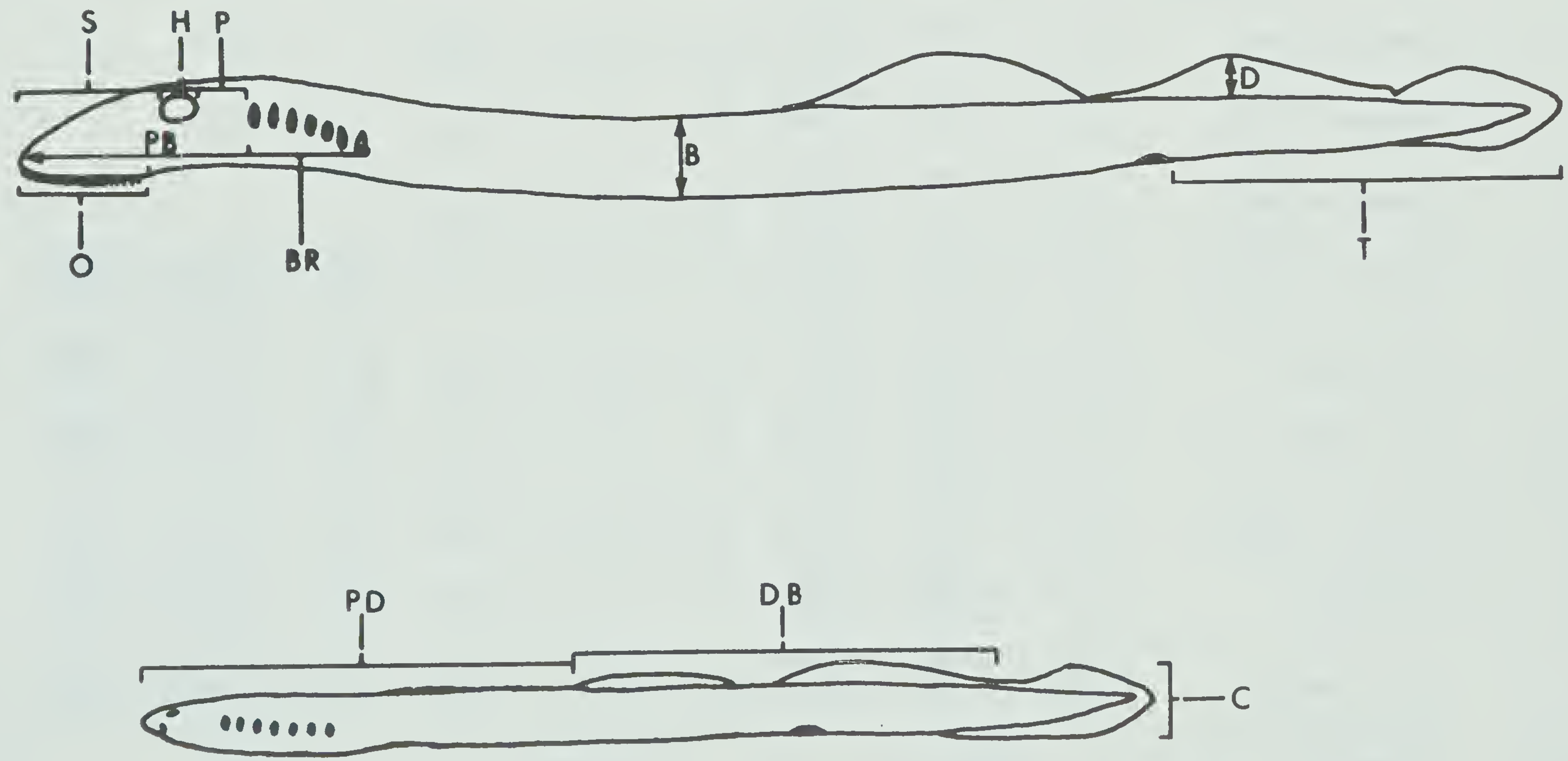

S
H
P
PB
O
BR
B
D
T
PD
DB
C

Table VI. *Regression line equations for a series of morphometric measurements on ammocoete, immature and adult lampreys*

Y(dependent variable) = a(constant) + b(slope)X(independent variable)

CHARACTER	AMMOCOETES	TRANSFORMED	ADULTS
Snout length	HR Y = -1.9632 + 0.7230X SR = -0.0001 + 0.2912X	HR Y = 2.5856 - 0.0481X	GSL Y = -1.4389 + 0.7963X SR = 3.0538 - 0.0051X
Postorbital	HR Y = -4.4980 + 1.1567X SR = -2.8298 + 0.7963X	HR Y = 1.7470 - 0.0590X	GSL Y = -3.3606 + 0.9467X SR = 1.9462 - 0.0069X
Branchial length	HR Y = -1.7260 + 0.9311X SR = 0.8798 + 0.3515X	HR Y = 3.1923 - 0.0626X	GSL Y = -2.6460 + 1.0549X SR = 3.3587 - 0.0116X
Tail length	HR Y = -5.1541 + 1.7819X SR = -1.5275 + 1.0466X	HR Y = 4.3426 - 0.0644X	GSL Y = -0.7830 + 0.9112X SR = 4.3927 - 0.0150X
Body depth	HR Y = -2.2782 + 0.8647X SR = -1.5889 + 0.6883X	HR Y = 2.5917 - 0.0593X	GSL Y = -5.1020 + 1.4100X SR = 2.5526 + 0.0579X
Dorsal fin height	HR Y = 6.3447 - 1.0880X SR = -2.5636 + 0.6615X	HR Y = 1.9830 - 0.0524X	GSL Y = -3.6241 + 1.0562X SR = 2.7063 - 0.0301X
Caudal fin depth	HR Y = 1.8285 - 0.0005X SR = -1.8554 + 0.7202X	HR Y =-3.6500 + 1.1186X	
Predorsal length	HR Y = -1.3031 + 1.1168X SR = 2.6182 + 0.2603X	HR Y = 7.4637 - 0.5755X	
Dorsal fin base	HR Y = -1.1236 + 1.0361X SR = 1.4572 + 0.4608X	HR Y = 3.1704 + 0.2226X	
Prebranchial length			GSL Y = 7.4615 - 0.7040X SR = 3.4864 - 0.0076X
Horizontal eye diameter			GSL Y = -0.4130 + 0.3743X HR = 1.5448 - 0.0064X
Oral disc diameter			GSL Y = -3.2544 + 1.0663X SR = 2.8047 - 0.0059X

HR-Hay River SR-Slave River GSL-Great Slave Lake

is suggestive of better ammocoete conditions in the Hay. Assuming that the ammocoete stage lasts for four years in each river then the Hay would require a faster growth rate because of the larger terminal ammocoete size.

The slope values for the transformed ammocoetes are generally negative and the absolute values approach zero. This must reflect the decrease in length which occurs at transformation (Berg 1931).

The growth rates obtained from the Slave River adults are extremely different from those obtained from the Great Slave Lake adults. The positive slopes from the Great Slave specimens and negative slopes for the Slave River specimens likely reflect stages of the life cycle. Generally the lake adults are feeding, have not yet matured and are quite likely still growing. The Slave River adults are all sexually mature. Their mean length is 26.6 (24.0-30.7) centimetres, which is considerably less than their Great Slave counterparts (Figure 9) captured in late summer. Parasitic lampreys are known to decrease in length prior to spawning (Zanandrea 1961) and this is undoubtedly shown in the slope values from the Slave River.

c. Ammocoete pigmentation.

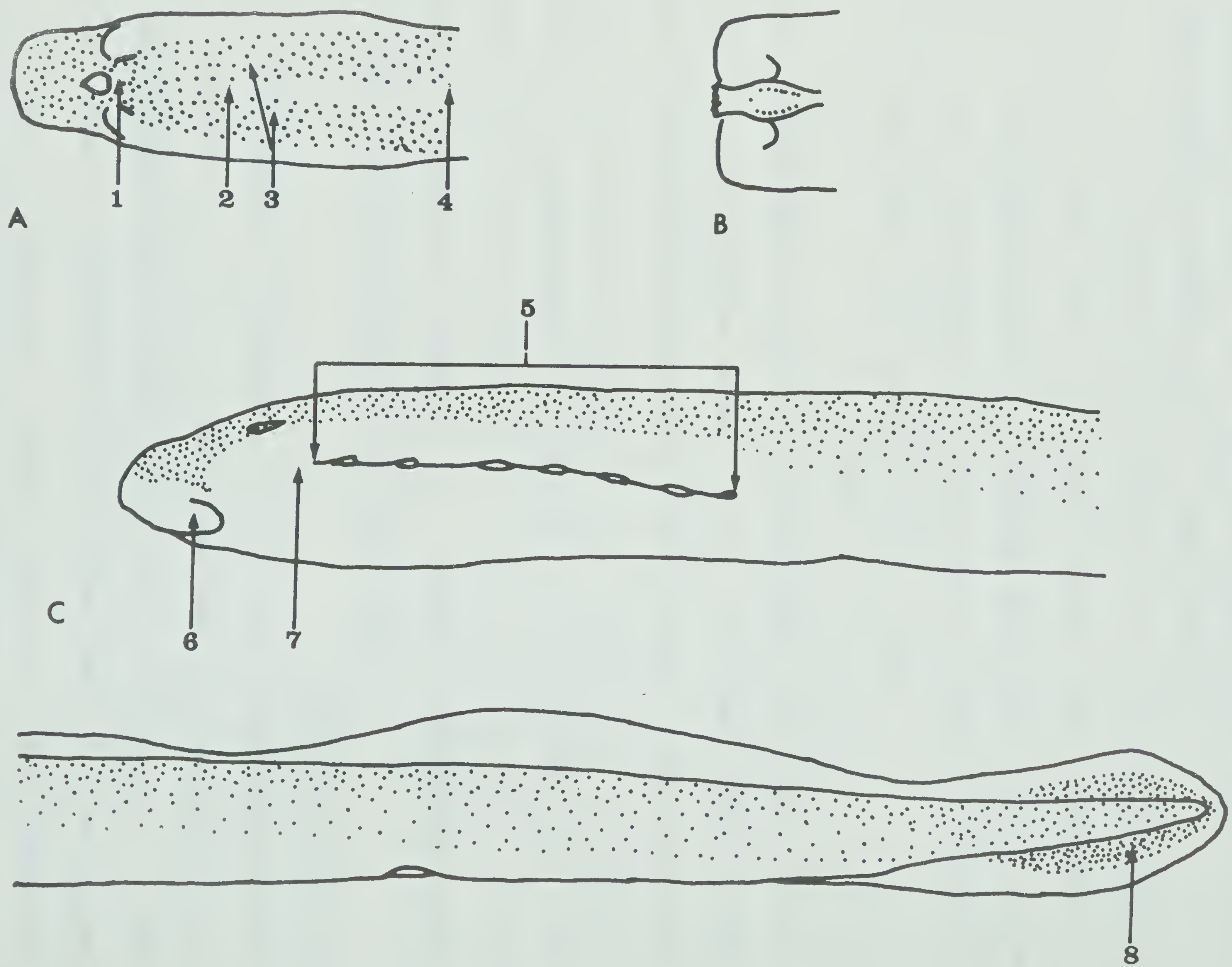
Vladykov (1950, 1960) has demonstrated the use of pigmentation characters for ammocoete identification. Observations were made upon 118 Hay River and 162 Slave River specimens captured from August 1 to 15, 1966. Each group was divided into length classes, i.e. less than 10.0 centimetres, 10.0 to 15.0 centimetres and more than 15.0 centimetres. The regions observed are illustrated in Figure 30.

i. Dorsal surface of head and trunk

Post-nostril area: In all ammocoetes the area of this unpigmented region always exceeds the nostril area. This area tends to become smaller in the larger ammocoetes and changes in shape from roughly rectangular to bilobed, i.e. it becomes constricted along the midline.

Figure 30. *Pigmentation areas of ammocoetes.*

A-dorsal view of head, B-dorsal view of precursor of the tongue, C-lateral view of the ammocoete. Areas referred to are: 1-post-nostril area, 2-cephalic dark line, 3-cephalic oblique muscular septa, 4-mid-dorsal band, 5-branchial region, 6-upper lip, 7-prebranchial blotch, 8-caudal fin. Based primarily on Vladykov (1950) and Vladykov and Follett (1960).



A
1
2
3
4
B
5
C
6
7
8

Cephalic dark line: This region is in the middle of the posterior section of the head. It is situated in the cartilaginous brain capsule and is very dark in colour. The region is hidden by pigmentation in all ammocoetes over 15.0 centimetres in length. Below this length, it is visible in 90 per cent of the Hay River specimens and 58 per cent of the Slave River specimens between 10.0 and 15.0 centimetres in length. Slave River ammocoetes less than 10.0 centimetres in length show it in 89 per cent of the cases.

It appears that as the ammocoetes become older this area becomes increasingly pigmented. The difference in pigmentation between Hay and Slave River specimens must at least partially reflect their age difference. In any case transformation in the Slave is at approximately 14.0 centimetres in contrast to approximately 19.0 centimetres in the Hay River. Hence the smaller Slave River ammocoetes are at an equivalent pigmentation stage as the large Hay River ammocoetes. This is further supportive evidence that 14.0 centimetre Slave River ammocoetes are in about the same stage of development as the 19.0 centimetre Hay River ammocoetes.

Cephalic oblique muscular septa: These dorsal extensions of myomeres are seen on either side of the cephalic dark line. In the large ammocoetes this area becomes masked by overlying pigmentation. In the 10.0 - 15.0 centimetre range they were visible in 77 per cent of the Slave River specimens and in 15 per cent of the Hay River specimens.

Mid-dorsal band: As the ammocoetes become larger, this area also becomes increasingly pigmented. The originally unpigmented band has become completely pigmented in 36 per cent of the ammocoetes over 15.0 centimetres. The unpigmented band is discernible on all the small Slave River ammocoetes, even though some difficulty arises in about 25 per cent of the cases. There are negligible differences in the 10.0 - 15.0 centimetre range.

One might expect the Slave River ammocoetes to be slightly paler due to the extreme turbidity. Here the value of a countershading coloration would be reduced.

ii. Lateral side of the head and trunk

Upper lip: The only factor considered here was whether or not pigmentation extended to the anterior margin of the lip. For ammocoetes greater than 15.0 centimetres in length it did so in 98 per cent of the cases. The margin is unpigmented in 48 per cent of the Hay River and 10 per cent of the Slave River ammocoetes in the 10.0-15.0 centimetre range. The unpigmented condition is found in all the small Hay River ammocoetes and in 61 per cent of the small Slave River ammocoetes. Once again increase in pigmentation seems correlated with age. The difference between the rivers reflects the smaller transformation size found in the Slave River. Hence on a corresponding basis the ammocoetes appear to be at the same stage of development.

Prebranchial blotch: This area extends from the rear of the upper lip to the first gill-opening. Descriptions here are quite subjective in that the area is described as sparsely pigmented or unpigmented. In the 10.0-15.0 centimetre range 58 per cent of the Hay River and 69 per cent of the Slave River ammocoetes are unpigmented. The remainder are sparsely pigmented. In the smaller ammocoetes 65 per cent of those from the Slave are unpigmented. Here again the remainder are sparsely pigmented. The variation between the two rivers here is very slight. Difference with age does not appear to be great.

Branchial region: Of concern here is the pigmentation in the region immediately dorsal to the gills. In some species it may extend to the upper margins of the gills (Vladykov 1960). It may be described in this species as either a broad unpigmented band or as a broad sparsely pigmented band. Most certainly pigmentation does not extend to the upper margin of the

gill slits.

In the 10.0-15.0 centimetre range this area is unpigmented in 85 per cent of the Hay River and 50 per cent of the Slave River ammocoetes. With the less than 10.0 centimetre specimens this area is unpigmented in all Hay River and 79 per cent of the Slave River ammocoetes.

iii. Tail region

Caudal fin: No differences were noted between the rivers in this category. In all ammocoetes the pattern is the same as shown in C, Figure 30. It is not of the "beavertail" type described for *Petromyzon marinus*.

iv. Peritoneum

In all ammocoetes examined, the dorsal half of the parietal peritoneum is heavily pigmented.

v. Tongue precursor

This region is shown in its dorsal aspect in B, Figure 30. It was dissected out using the method outlined by Vladykov (1950). The bulb is rarely pigmented on the ventral surface, but the dorsal surface is invariably pigmented. This is true also of *Lampetra lamottenii* but not of *Petromyzon marinus*, in which it is seldom pigmented (Vladykov 1960). The general pattern in the Great Slave ammocoetes is two heavily pigmented parallel lines extending anterior on the bulb until it begins to narrow. Frequently there is a spot on the elastic ridge slightly anterior to where the parallel lines cease. No differences were seen with location of capture.

From the above descriptions I would not feel justified to state that a distinct difference occurs between ammocoetes of the Hay and Slave rivers with regard to pigmentation characters. The primary reason for the above discussion is to provide a physical description of ammocoetes from the Great Slave Lake region such that they may be compared with collections elsewhere. They do seem very similar to Vladykov's (1960) description of *Entosphenus lamottenii*, which

also has the same adult dentition but is non-parasitic.

G. Prey

A summary of fish examined from commercial nets and from Fisheries Research Board experimental fishing can be seen in Table 7. Species and location of attacks are shown in Figures 31 and 32. In addition to the 14,394 fish represented above, another 900 were examined from the Hay River (Table 8), 158 pike from Sandy Creek and 1966 river surveys, and 50 fish from in front of the Hay River office of the Fisheries Research Board. Only two scarred fish were found in the group, not including commercial and experimental fishing data. These were a burbot and a pike, both from the Hay River mouth. Hence a total of 15,502 fish were examined for lamprey attack. Figure 33 gives the locations on Great Slave from which fish were examined and shows where scarred fish were found. Figure 34 illustrates scarred fish.

An interesting relationship emerges when the 1967 scarring data is related to time and proximity to the Hay River (Table 9). Using whitefish as an index, note how high the percentage of scarring is in time period 12 (June 16-30) directly off the Hay River. At Point de Roche, which is only 13 miles west the rate drops to approximately one half or 3.9 per cent. By time period 15 (August 1-15) the Hay River value had dropped to 2.0 from 11.2. This is not far removed from values a short distance east for the same time period, e.g. combined Sandy Creek and Buffalo River is 2.7.

An earlier tagging study has suggested that fish populations in Great Slave are relatively non-migratory (Keleher 1963). Also suggestive of this condition is that gill netting is frequently more successful in the Hay River closed area than a few miles away.

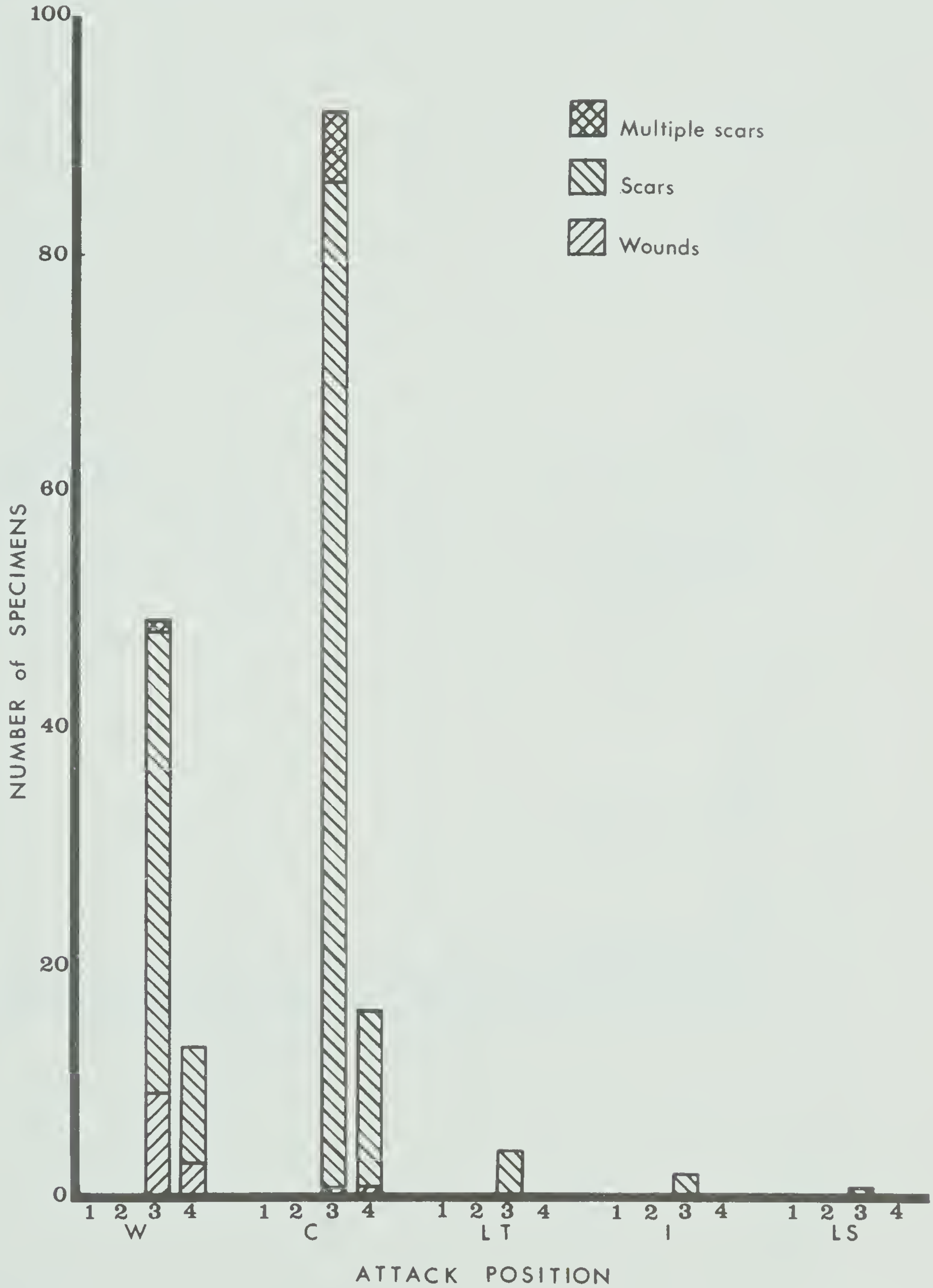
If the above is the true situation it suggests that a dispersion of

TABLE VII. *Number of fish examined and percentage showing lamprey attacks in 1966 summer experimental and commercial fishing samples.*

AREA	A		D		E		F		G		H		K		L		M		N		TOTAL	
SPECIES	number	%	number	%	number	%	number	%	number	%	number	%	number	%	number	%	number	%	number	%	number	%
whitefish	841	1.1	607	1.8	931	2.4	851	1.3	200	1.5	87	0.0	553	0.4	2,008	0.0	957	0.1	76	0.0	7,111	0.8
cisco	919	8.8	489	5.7	80	1.3	0	0.0	0	0.0	21	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1,509	7.3
inconnu	10	0.0	6	33.0	2	0.0	11	0.0	52	0.0	1	0.0	0	0.0	0	0.0	0	0.0	0	0.0	82	4.1
lake trout	41	2.4	22	4.5	8	0.0	10	0.0	62	1.6	0	0.0	0	0.0	220	0.0	154	1.9	288	0.0	805	0.7
longnose sucker	955	0.1	6	0.0	6	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	967	0.1
pike	28	0.0	3	0.0	1	0.0	124	0.0	0	0.0	0	0.0	0	0.0	4	0.0	43	0.0	4	0.0	207	0.0
yellow walleye	0	0.0	0	0.0	0	0.0	84	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	84	0.0
burbot	51	0.0	56	0.0	31	0.0	0	0.0	0	0.0	15	0.0	0	0.0	0	0.0	0	0.0	0	0.0	153	0.0
TOTAL	2,845	3.2	1,189	3.5	1,059	2.2	1,080	1.0	314	1.3	124	0.0	553	0.4	2,232	0.0	1,154	0.4	368	0.0	10,918	1.6

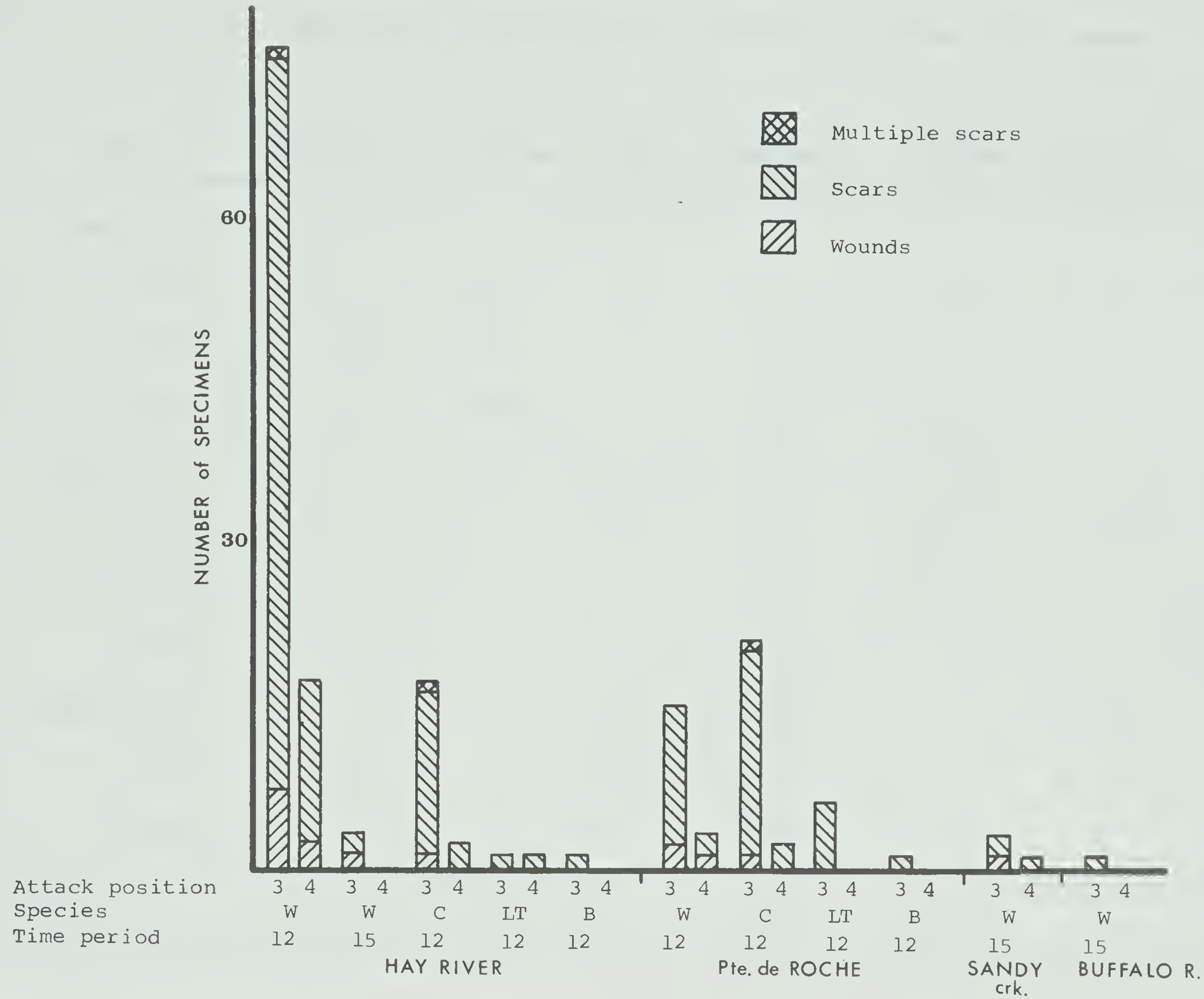
Figure 31. *Summer scarring data plotted as to position of the attack and species.*

I-inconnu, C-cisco, LS-longnose sucker, LT-lake trout, W-whitefish. The numbers 1, 2, 3, 4 refer to the position of attack as illustrated in Figure 4.



Multiple scars
Scars
Wounds
NUMBER of SPECIMENS
100
80
60
40
20
0
1 2 3 4
W
1 2 3 4
C
1 2 3 4
LT
1 2 3 4
I
1 2 3 4
LS
ATTACK POSITION

Figure 32. *1967 summer scarring data plotted as to position of the attack, time of capture, location of capture and species.* B-burbot, C-cisco, LT-lake trout, W-whitefish.



Multiple scars
Scars
Wounds
NUMBER of SPECIMENS
60
30
Attack position
Species
Time period
3 4 3 4 3 4 3 4 3 4 3 4 3 4 3 4 3 4 3 4 3 4
W W C LT B W C LT B W W
12 15 12 12 12 12 12 12 12 15 15
HAY RIVER
Pte. de ROCHE
SANDY crk.
BUFFALO R.

Table VIII. *Fish examined from the Hay River 1967 summer.*

Nets/Night	Date	Whitefish	Inconnu	Pike	Y.Walleye	L.Sucker	W.Sucker	Burbot	Total
1/1	June 1-7				2				2
4/1	8-15		4			4			8
19/1	16-22	2	37	4	5	54		4	106
13/1	23-30	1	13	2	43	61		2	163
3/1	July 1-7		1		5	1			7
7/1 4/2	8-15			1	21	12		1	35
3/3	16-22				3	3			6
12/1	23-31			2	154	9			165
6/1	August 1-7			1	93	4	1	1	100
9/1	8-15	2		1	104	9			116
18/1	16-22	9		2	211	11			233
	TOTAL	14	55	13	639	170	1	8	900

Figure 33. *Areas on Great Slave Lake where fish were found with evidence of lamprey attack.*

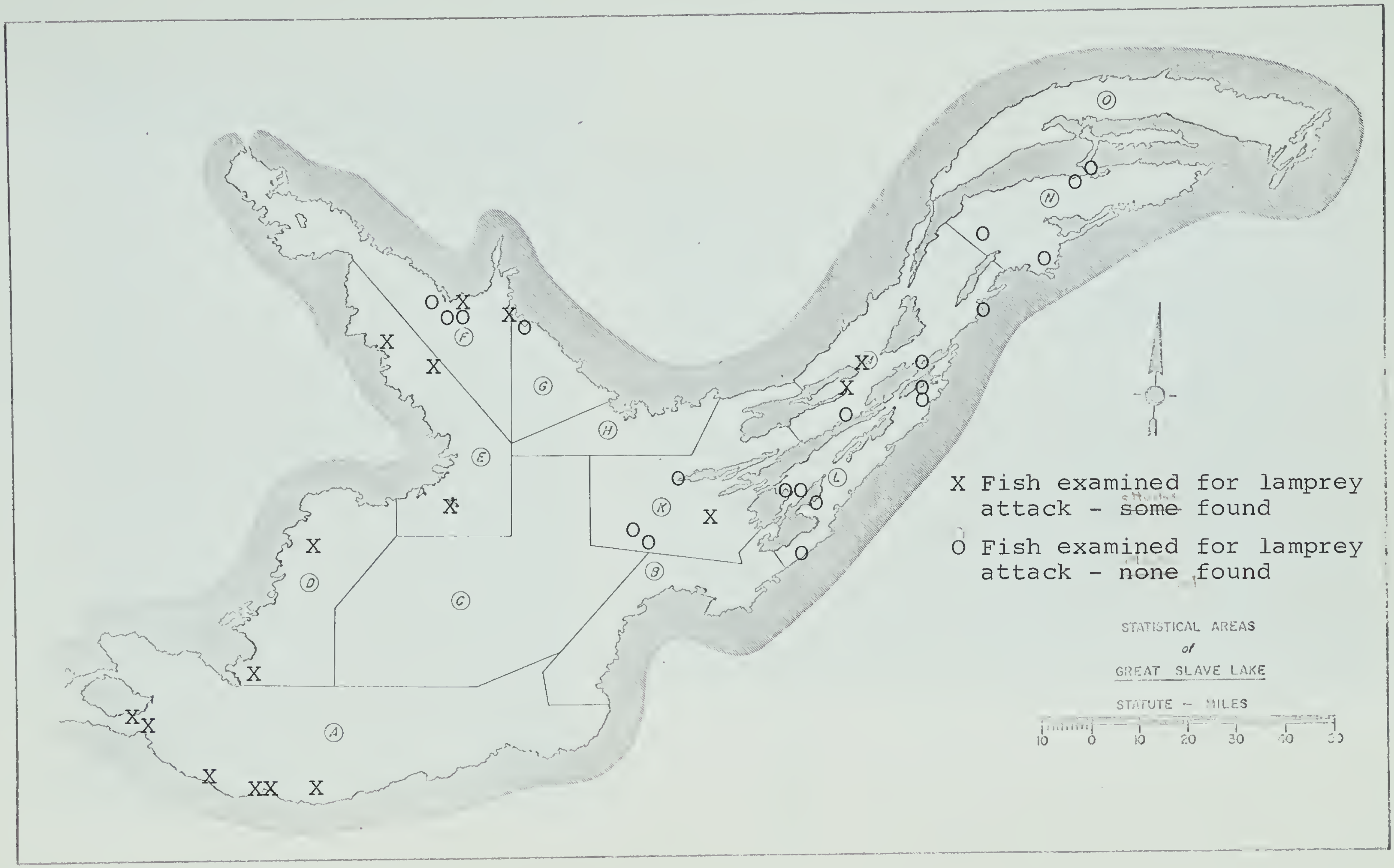

X Fish examined for lamprey attack - ~~some~~ found
O Fish examined for lamprey attack - ~~none~~ found
STATISTICAL AREAS
of
GREAT SLAVE LAKE
STATUTE - MILES
10 0 10 20 30 40
A
B
C
D
E
F
G
H
K
L
N
O

Figure 34. *Examples of scarred fish.*

Table IX. *Number of fish examined and percentage showing lamprey attacks in 1967 summer.*

Location Time Period Species	N of Hay River 12(June 16-30) number	 %	N of Hay River 15(August 1-15) number	 %	Point de Roche 12(June 16-30) number	 %	Sandy Creek 15(August 1-15) number	 %	Buffalo River 15(August 1-15) number	 %
whitefish	831	11.19	397	2.01	284	6.33	161	2.48	23	4.34
cisco	446	4.26	3	0.00	579	3.97	7	0.00	0	0.00
inconnu	3	0.00	2	0.00	2	0.00	8	0.00	19	0.00
lake trout	31	6.45	0	0.00	89	6.74	5	0.00	0	0.00
longnose sucker	71	0.00	71	0.00	153	0.00	98	0.00	13	0.0
burbot	74	1.35	3	0.00	111	0.90	6	0.00	1	0.00
TOTAL	1,456	7.90	476	1.68	1,218	3.94	285	1.40	41	2.44

parasitic lampreys is occurring from the Hay River mouth, but not until late spring or early summer. Table 9 shows that the pattern mentioned above for the whitefish is found in other species as well. Note also that the 1967 scarring rate for area A is 5 per cent in relation to the total lake value of 1.6 (Table 7). The 1966 area A value is 3.2 per cent but this includes 950 longnose suckers from nets set at Slave Point. Hence this concept of dispersion of adults from the Hay River mouth is supported by information from a variety of species.

The 1966 data (Table 7) certainly suggests that parasitic lampreys are restricted to the western half of Great Slave Lake. Unfortunately no information is available from area C as it is seldom utilized by the commercial fishery. Areas A, D, E, and F show a decrease in scarring in direct relation to their distance from Hay River. This is based upon 6,173 fish. The scarring rate of the north arm region, when compared to area A, where spawning is known to occur, does not suggest a local spawning area.

Figures 31 and 32 indicate that positions three and four (ventral to the lateral line-see methods) are preferentially attacked. Only in four cases was multiple scarring over two positions seen to occur. This appeared to be a case of initial attachment and then movement after.

H. Mortality

1. Biological. In the course of the study a total of 1,283 fish stomachs were examined, including 219 pike, 176 lake trout, 69 inconnu, 615 yellow walleye and 204 burbot.

Ammocoetes were found in four burbot seined off the Hay River mouth in late May 1967. One pike captured in the vicinity of an ammocoete bed contained several ammocoetes and an adult lamprey. Another pike from the main channel of the Hay River contained a mature adult. Thus only 0.5 per

cent of the fish examined had preyed upon lampreys.

Further Great Slave Lake information supports the above. Bishop (pers. com.) upon examining 820 pike and 578 lake trout found lamprey adults in two pike from the Mackenzie River region. Fuller (1955) found none in 196 inconnu. Rawson (1951) reported examining 650 trout, 116 yellow walleye and 87 burbot without recording a lamprey. He does report hearing about one in a burbot from Hay River and from an inconnu near Gros Cap. Keleher (pers. com.) reports none from 48 pike taken at Sandy Creek nor from 500 trout taken at Taltheilei Narrows.

Mr. Eric Hagglund, of Paradise Gardens on the Mackenzie Highway, has reported catching yellow walleye with ammocoetes in their stomachs. None of our information supports this, although occasionally people have brought ammocoetes to the Fisheries Research Board office, having removed them from yellow walleye stomachs. It may be possible that our nets were not located where yellow walleyes would have access to ammocoetes.

Occasionally rumors reached us about fishermen at Jones Bar on the west shore catching pike which are gorged on ammocoetes. These reports have not been confirmed nor do I have any reason for believing them to be true. Frequently leeches (Hirudinea) are mistaken for ammocoetes by people of the area.

Appendix 1 lists stomach contents of all fish examined.

Mr. Bert Edge, who is in charge of the water treatment plant at Fort Smith, stated on May 13, 1967 that he has seen sea gulls eating lampreys when the water intake reservoir is emptied. Lampreys have been recorded in gull stomachs previously (Merrell 1959) and in mergansers (Lindroth 1955).

It would appear that ammocoetes in a bed should be relatively safe from predation.

2. Non-biological. One factor which likely kills many ammocoetes is their

becoming trapped in pools which soon dry up due to falling water levels. When such pools are shocked along the Hay River ammocoetes invariably appeared.

I. Parasites

The cestode tapeworm *Triaenophorus* (identified by Dr. J. C. Holmes) was found in the coelom of a few adult lampreys. Those seen correspond to Miller's (1952) description of the plerocercoid stage. Miller records that in European fishes it is common to find plerocercoids naked in the flesh, i.e. not enclosed in cysts. In North America this has only been recorded in yearling coregonines. Miller (1952) found such plerocercoids in ciscoes from Lake Winnipeg and from Baptiste Lake, Alberta. He also reports that Lawler found all the plerocercoids to be naked in the infected ciscoes and whitefish of six inches and less from Hemming Lake, Manitoba.

The naked plerocercoids in the coelom of the adult lampreys could only have been acquired through ingestion of *Cyclops* by the ammocoete. Infestation could not have occurred by ingesting cysts from a coregonid fish as this stage of the parasites' life cycle is not capable of penetrating the intestine wall. The intestine of the second intermediate host is penetrated during the procercoid - plerocercoid transformation which occurs after the first intermediate host, *Cyclops*, reaches the second intermediate host's intestine. Hence this must have been what has happened or else the plerocercoid would be in the lamprey's intestine rather than in the coelom.

H. Discussion

Berg (1931) mentions the existence of *Lampetra japonicus kessleri*, a small river form as distinct from *Lampetra japonicus septentrionalis*, the Arctic Lamprey. Zanandrea (1961) points out that *kessleri* is a non-parasitic subspecies. It was shown in Figure 14 that some transformed lampreys show

surprising gonadal development for their size. When related to length (Figure 9) and sexual condition of Great Slave Lake adults, it does appear that a non-parasitic subspecies may be present. Recall also the difference between the two adults captured in trap nets during 1967 (Figures 7, 8).

Berg (1930) separates his subspecies on the basis of transformation size, where ammocoetes are either larger (*kessleri*) or smaller (*septentrionalis*) than the adults. Most Hay River transformed lampreys are smaller than the Great Slave Lake adults. However a few adults have been taken which are four or five centimetres shorter than full grown ammocoetes. Included here are four taken at the mouth of the Mackenzie River from pike stomachs. Unfortunately accurate lengths cannot be given because digestion of the specimens had proceeded too far. The gonads of the Mackenzie mouth specimens were nearly mature.

Data from a few adults from Great Slave Lake which are smaller than newly transformed adults from the Hay River may be cited:

1)	unknown 1955	length 16.1 cm	female	sexual stage 2	area ?
2)	July 10 1956	14.2	female	2	A
3)	July 5 1962	16.1	female	3	A
4)	July 5 1956	14.2	unknown	0	A
5)	July 8 1960	15.0	unknown	0	A
6)	July 16 1960	13.4	unknown	0	K

While the above adults are nearly all from area A, more specifically they tend to be from the eastern part of the area, i.e. near the Slave River mouth. Transformation occurs in the Hay River beginning in August. Transformation size in the Slave River of two specimens was 14.0 and 14.2 centimetres. Transformed ammocoetes are not available in the Slave during the first two weeks of August hence the above adults are not likely from the Slave system. How also are the small specimens from the Mackenzie explained. The size of the Slave River spawning adults is about 26.6 centimetres, as noted in the section on Morphometry. The adults listed above are too small to be late Slave River spawners.

While the evidence is not conclusive there may well be a non-parasitic subspecies in the lake. By chiefly using the fishery as a source of adults primarily parasitic adult lampreys appear in our collections. Zanandrea (1961) points out that only by finding a mature ammocoete can a positive statement be made. Such an ammocoete has not been seen.

The distribution map shows a concentration of adult lampreys in the north arm area of the lake. These were captured only in late August and September, despite constant fishing pressure through the summer season. Generally these specimens are of large size, with gorged intestines. Their gonads are identifiable but have not yet begun to fill the coelom. Due to the size of these lampreys (many exceed 30.0 centimetres in length), their sexual state and their intestinal condition, they cannot be transformed lampreys of the year. Surveys of the area suggest that spawning does not occur here.

In September transformed lampreys are still present in the Hay River and the large size of ammocoetes taken at that time indicates that more will transform in the near future. It is possible that these lampreys do not enter the lake until late fall or even winter.

Spring scarring information from the Hay River region shows a high degree of parasitism off the river mouth but noticeably less only 13 miles west. This difference disappears within a few weeks, even though fish populations apparently do not move much. It is possible that shortly after breakup a dispersion of adults occurs from these spawning rivers on the south shore. If the adults travelled generally in one direction, either along the shore or across the main body of the lake, a concentration along the north shore would occur. The straight line distance from Hay River to Yellowknife is only 120 miles. This does not seem to be an excessive distance to travel in a three month period.

Previously mentioned was the decline in scarring rates through areas D, E, F and G. Few adults have been recorded in D but this is likely because it is one of the earliest areas to be closed to fishing by the Department of Fisheries. Scarring information from the area is solely from Fisheries Research Board nets.

By fall, a large population may be found in the north arm. If they are to return to the Hay and Slave rivers the following spring, intestinal degeneration, cessation of feeding and gonadal development would occur in mid-winter. The two adults available from the winter fishery were both taken off the Simpson Islands in December. They fit the above description. Also this cessation of feeding at this time of year would explain why adult lampreys are so seldom taken in the winter fishery. Further to this, all adults taken off the Slave or Hay river mouths in June have been in spawning condition.

VI. SUMMARY

1) A total of 3,076 ammocoetes, 78 immature and 112 adult lampreys were collected during a study of the Arctic Lamprey of Great Slave Lake, N.W.T. This study took place during the summers of 1966 and 1967. Collections primarily involved the use of electro-shocking gear.

2) A survey of twenty-six rivers entering Great Slave Lake showed lampreys to be present only in the Hay, Slave and Mackenzie.

3) Within Great Slave Lake, Arctic Lampreys have only been located west of the Simpson Islands, i.e. the entire East Arm region is not utilized by this species.

4) Length-frequency distributions from the Hay River suggest an ammocoete period of four years.

5) A marking study involving 537 Hay River ammocoetes suggests a population in the neighbourhood of 30,000. This is undoubtedly low as we can neither capture nor mark the very small ammocoetes.

6) A growth study on 74 ammocoetes was not successful.

7) One hundred and nine adult lampreys, 55 immature lampreys and 531 ammocoetes were examined for a series of morphometric, meristic and pigmentation characters. Differences seen have been interpreted as due to river environments of the animal rather than due to implications of a taxonomic nature.

8) Spawning occurs in June or early July. Egg counts were done on 18 mature female lampreys yielding a mean of 21,415 (9,790-29,780).

9) A total of 15,502 fish were examined for lamprey attack and 1,283 fish stomachs were checked for evidence of predation. Only 0.5 per cent of the fish examined had preyed upon lampreys. The scarring rate for Great Slave Lake as a whole was 1.6 per cent. The species primarily attacked

are whitefish, cisco, inconnu and lake trout. Attacks are usually made ventral to the lateral line.

10) In the spring scarring rates were found to decrease directly with distance from the Hay River mouth. This is considered to be correlated with parasitic lamprey dispersion from this area. The differential scarring rate disappears as the summer progresses.

11) The present state of the taxonomy of the Arctic Lamprey is discussed and the existence of a non-parasitic subspecies postulated.

12) The presence of *Triaenophorus* in the coelom of adult lampreys is discussed and it is suggested that infestation must have occurred through ingestion of *Cyclops* during the ammocoete stage.

VII. LITERATURE CITED

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VIII. APPENDICES

APPENDIX A. *Contents of stomachs of fish examined during 1966 and 1967 summers.*

SPECIES	W	C	B	CO	S	TP	YW	P	G	L	I	H	E	UF	M	$\dot{\bar{c}}$L	TOTAL
Pike	9	26	9	4	0	2	1	1	1	2	13	2	120	28	1	0	219
L.Trout	0	61	2	0	0	0	0	0	0	0	1	0	33	25	0	53	175
Inconnu	0	6	0	1	0	0	0	0	0	0	0	0	47	14	0	0	68
Burbot	0	24	0	5	0	3	0	0	0	4	1	0	49	43	0	75	204
Y.Walleye	0	3	0	0	1	0	3	0	0	0	4	0	499	104	0	0	614
TOTAL	9	120	11	10	1	5	4	1	1	6	19	2	748	128	1	128	1,280

Legend: B-burbot, C-cisco, CO-cottidae, E-empty, G-grayling, H-hirudinea, I-insecta, L-lamprey, $\dot{\bar{c}}$L-contents not recorded but did not contain lampreys, M-mouse (likely Peromyscus), P-pike, St-stickleback, TP-troutperch, UF-unidentified fish, W-whitefish, YW-yellow walleye

Appendix B. *Hay River water chemistry during 1967 summer.*

TEST	MAY 18		JUNE 1		JUNE 16		JULY 1		JULY 16		AUG. 1		AUG. 16	
	Bed 1	Bed 5	Bed 1	Bed 5	Bed 1	Bed 5	Bed 1	Bed 5	Bed 1	Bed 5	Bed 1	Bed 5	Bed 1	Bed 5
Alk(ppm)	60	-	20	58	40	50	25	56	58	60	50	35	45	48
Cl (ppm)	5.0	-	5.0	5.0	6.0	4.5	5.0	4.5	5.0	5.0	5.0	5.0	5.0	4.5
Cu (ppm)	0.00	-	0.03	0.00	0.07	0.02	0.07	0.10	0.09	0.07	0.04	0.03	0.02	0.04
Ca (ppm)	62	-	72	73	90	100	105	105	108	110	90	95	105	110
Mg (ppm)	28	-	28	27	40	30	45	45	47	35	40	36	43	40
Fe (ppm)	5.40	-	1.01	0.85	0.82	0.15	1.13	1.18	0.50	0.55	0.81	0.75	0.63	0.68
Mn (ppm)	0.00	-	1.78	0.20	0.25	1.10	0.80	0.50	0.40	0.80	1.50	2.25	1.70	1.20
NO_4 (ppm)	6.60	-	3.60	0.20	1.40	0.05	1.80	1.60	3.90	2.10	3.90	3.20	0.85	1.80
O_2 (% Sat.)	36	-	41	35	69	64	79	77	95	87	69	58	70	75
oPO_4 (ppm)	0.70	-	0.10	0.11	0.10	0.15	0.06	0.05	0.05	0.00	0.02	0.00	0.10	0.15
mPO_4 (ppm)	0.00	-	210	125	0.08	0.20	0.24	0.40	0.10	0.20	0.08	0.38	0.10	0.05
SO_4 (ppm)	300+	-	0.00	0.00	94	87	97	98	78	85	75	87	87	90
Tur (ppm)	440	-	132	155	40	53	33	20	43	35	60	60	55	52

Legend: Alk-total alkalinity, Cl-chloride, Cu-copper, Ca-calcium hardness, Mg-magnesium hardness, Fe-iron, Mn-manganese, NO_4-nitrate nitrogen, O_2-dissolved oxygen, oPO_4-ortho phosphate, mPO_4-meta phosphate, SO_4-sulfate, Tur-turbidity

APPENDIX C. *Water chemistry of some rivers examined during 1966 and 1967.*

LOCATION (river)	YEAR	Alk ppm	Cl ppm	Cu ppm	Ca ppm	TH* ppm	Fe ppm	NO_3 N ppm	o PO_4 ppm	SO_4 ppm	TUR ppm
Buffalo	66			0.75	56				0.10	43	93
Campbell	66	110	2.5	0.10	66		1.25	0.70		10	20
Chadabuktu	66			0.18	1125		0.15		0.05	300+	3
Francois	66	90	8	0.08	40		0.08	0.10		8	9
Frank Ch.	66	30	2.5	0.06	14		0.05	0.05	0.30	7	15
Goulet Bay	66	87	15	0.10	38		1.65	1.00		1	18
La Loche	66			0.10	22		0.05		0.10	18	0
Little Buffalo	66			0.36	870		0.23		0.05	300+	16
Mosquito Creek	66			0.25	918	1032	0.07			300+	0
Narrow Island	66	37	7	0.12	17		0.05	0.10		4	1
Northwest	66	210	5	0.22	230		0.06	1.70	0.60	200	20
Pauline	66	26	5	0.13	11		0.02	0.05		5	2
Slave	66			0.70	65		1.1		0.25	40	125
Slave	67			0.05	60	82	0.47			22	40
Stagg	66	43	5.5	0.08	19		0.15		0.50	3	7
Taltson	66			0.12	11		0.17		0.10	3	5
Thuban	66			0.14	28		0.10		0.15	3	5
Trout Rock	67			0.15	0.26	0.45	0.22			4	11
Yellowknife	66	24	4.5	0.10	11		0.05		0.15	4	8
Yellowknife	67			0.15	0.05	0.11	0.05			3	2
Wool Bay	66	81	10	0.12	61		0.16	0.60		15	5

*TH-total hardness

APPENDIX D. *Relative depth (cm) of the Hay River during 1967 summer.*

date		depth
May	30	271
	31	263
June	1	257
	2	250
	3	246
	4	242
	5	238
	6	232
	7	230
	8	225
	9	223
	10	221
	11	219
	12	217
	13	217
	14	214
	15	210
	16	208
	17	205
	18	203
	19	203
	20	200
	21	195
	22	192
	23	-
	24	189
	25	186
	26	185
	27	182
	28	181
	29	-
	30	180
July	1	176
	2	175
	3	172
	4	177
	5	175
	6	173
	7	178
	8	-
	9	-
	10	178
	11	178
	12	179
	13	179
	14	180
	15	179

date		depth
July	16	-
	17	179
	18	178
	19	-
	20	-
	21	-
	22	-
	23	-
	24	-
	25	180
	26	179
	27	182
	28	184
	29	185
	30	186
	31	186
August	1	185
	2	181
	3	-
	4	188
	5	188
	6	197
	7	188
	8	183
	9	179
	10	180
	11	183
	12	182
	13	-
	14	179
	15	178
	16	175
	17	165
	18	174
	19	180
	20	172
	21	170
	22	170
	23	176
	24	-
	25	171
	26	171
	27	172
	28	172
	29	-
	30	-
	31	-

APPENDIX E. *Maximum and minimum temperatures (°F) from the Hay River in the vicinity of bed 1.*

date		min-max	
May	30	56	58
	31	57	59
June	1	59	61
	2	60	61
	3	60	61
	4	59	61
	5	56	58
	6	56	57
	7	56	59
	8	57	58
	9	54	57
	10	54	56
	11	59	63
	12	57	59
	13	57	59
	14	59	60
	15	60	60
	16	59	60
	17	61	62
	18	62	63
	19	66	69
	20	65	66
	21	62	64
	22	61	63
	23	-	-
	24	61	64
	25	62	69
	26	67	69
	27	64	68
	28	67	69
	29	-	-
	30	65	68
July	1	66	67
	2	64	67
	3	67	68
	4	65	67
	5	61	62
	6	61	62
	7	65	66
	8	-	-
	9	-	-
	10	64	67
	11	66	67
	12	67	69
	13	65	69
	14	65	67
	15	65	67

date		min-max	
July	16	-	-
	17	67	70
	18	71	72
	19	-	-
	20	-	-
	21	-	-
	22	-	-
	23	-	-
	24	-	-
	25	62	67
	26	61	62
	27	63	64
	28	64	65
	29	62	63
	30	66	68
	31	67	68
August	1	64	66
	2	64	65
	3	-	-
	4	66	67
	5	65	66
	6	59	63
	7	62	63
	8	61	63
	9	62	63
	10	64	68
	11	66	68
	12	67	68
	13	-	-
	14	64	65
	15	65	66
	16	62	63
	17	59	60
	18	60	63
	19	63	64
	20	66	69
	21	67	69
	22	67	69
	23	64	66
	24	-	-
	25	60	63
	26	60	63
	27	60	64
	28	60	63
	29	-	-
	30	-	-
	31	-	-

APPENDIX F. *Maximum and minimum air temperatures recorded at the Hay River office of the Fisheries Research Board during 1967 summer. All readings in °F.*

date		min	max	date		min	max
June	1	-	-	July	16	47	89
	2	-	-		17	47	91
	3	-	-		18	56	82
	4	30	42		19	-	-
	5	30	49		20	-	-
	6	37	75		21	-	-
	7	38	61		22	-	-
	8	30	36		23	-	-
	9	28	43		24	-	-
	10	34	75		25	41	65
	11	-	-		26	42	73
	12	33	58		27	53	58
	13	41	70		28	50	72
	14	43	79		29	-	-
	15	35	45		30	-	-
	16	33	61		31	50	71
	17	37	77				
	18	39	62	August	1	53	63
	19	39	65		2	43	79
	20	41	62		3	-	-
	21	39	49		4	40	68
	22	33	55		5	36	70
	23	38	80		6	44	54
	24	50	79		7	47	58
	25	54	94		8	43	79
	26	45	57		9	50	85
	27	50	71		10	60	80
	28	46	89		11	59	80
	29	49	73		12	50	75
	30	46	63		13	49	76
					14	47	59
July	1	45	72		15	44	53
	2	44	78		16	37	53
	3	49	74		17	38	78
	4	46	57		18	54	69
	5	45	69		19	54	69
	6	45	77		20	54	84
	7	45	72		21	54	76
	8	-	-		22	52	69
	9	-	-		23	52	58
	10	-	-		24	46	60
	11	50	89		25	44	65
	12	50	79		26	47	68
	13	43	67		27	43	65
	14	51	64		28	47	66
	15	47	64		29	-	-
					30	-	-
					31	-	-